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Opaque Segholates Revisited: The Glottal Stop in Standard Modern Hebrew Phonology

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Abstract. In this project, I will address the debatable phonemic status of the glottal stop /ʔ/ in the phonological inventory of Standard Modern Hebrew speakers through an investigation of apparent opacity in /ʔ/-final segholate nouns. The glottal stop alternates with Ø in Modern Hebrew, is never produced in codas and rarely produced elsewhere. Some researchers propose that its realization may be the result of historical influence rather than productive phonological rules. Pertinent to this debate is the underlying representation of Modern Hebrew segholate nouns; a nominal class with a unique stress pattern. These nouns are typically analyzed with a triconsonantal root template, but those with /ʔ/-final roots do not surface with final /ʔ/ in their singular forms. This phenomenon is problematic for Standard Optimality Theory (Prince & Smolensky 1993), and calls into question the strategy with which speakers deduce the underlying forms of neutralized segments. I conducted an elicitation task in which four native speakers were asked to produce a total of twenty novel, /ʔ/-final words: ten 3fs verbs and ten plural segholate nouns. The results provide evidence that, while the glottal stop retains its phonemic status in Modern Hebrew, speakers prefer to realize underlying final glottal stops as a glottalization period in nouns, and to assume underlying final /j/ over final /ʔ/ in verbs. Additionally, although the participants consistently posited a triconsonantal root for verbs, they exhibited only a weak preference for a third root consonant in nouns, indicating that this template may not be obligatory for Modern Hebrew nominals.

Plain English Abstract. The phonemic status of the glottal stop /ʔ/ in Standard Modern Hebrew is debatable. While historically underlying, the glottal stop is never produced in codas and rarely elsewhere. Some researchers propose that its realization may be the result of historical influence rather than productive phonological rules. Whether the glottal stop is underlying in Modern Hebrew segholate nouns, a nominal class with a unique stress pattern, is pertinent to this wider debate. Glottal stop-final segholate nouns in Modern Hebrew do not surface with final /ʔ/ in their singular forms, a phenomenon that is problematic for Standard Optimality Theory (Prince & Smolensky 1993), and raises the question: how do speakers assign the underlying forms of segments that do not surface? Four native speakers participated in an elicitation task in which they were asked to produce a total of twenty novel, glottal stop-final Standard Modern Hebrew words, all of which belonged to grammatical classes that typically require a three-consonant root. Ten of these novel words were verb forms with a transparent derivation, and ten were plural segholate nouns with opaque derivations. The results indicate that while the glottal stop retains its phonemic status, speakers preferred to assume an underlying final /j/ over final /ʔ/ in the verbs. Furthermore, speakers produced a glottal stop more frequently for the novel verb forms than the novel nouns, providing evidence that a two-consonant root may be allowed for Modern Hebrew nouns with an underlying glottal stop.

Keywords: Phonology; Phonological Theory; Modern Hebrew; Semitic Phonology; Abstract Representation; Optimality Theory

1 Introduction

1.1 A History of Modern Hebrew

The language of inquiry for this paper is Standard Modern Hebrew, the variety of Modern Hebrew used by the majority of native speakers. While Ancient Hebrew died out as a native language around the third century BCE, diasporic Jewish communities retained it as a lingua franca and liturgical language for over 1700 years. These diasporic communities developed different oral traditions during this time

period that established ‘grapheme-to-phoneme’ equivalence with distinct pronunciation rules (Blanc 1968). These oral traditions were derived from the Tiberian vocalization system, which emerged between 600-800 AD and likely reflects an older, orally transmitted pronunciation tradition (Bentur 1978). The 19th century Jewish Enlightenment in Europe saw the revival of Hebrew as a mother tongue by predominantly Ashkenazi, Slavic-speaking Jewish linguists. These linguists used the varying oral traditions, comparisons to other Semitic languages, and biblical transliterations with the goal of having each grapheme correspond to a single sound (Bentur 1978).

This attempt to ‘recover what was encoded orthographically’ was disrupted by the fact that the guttural sounds pronounced in the Tiberian vocalization system and the Sephardic and Yemenite oral traditions, namely /q/, /h/, and /ʕ/, were not accessible for Ashkenazi speakers (Bentur 1978). The early speakers of Standard Modern Hebrew (hereafter ‘Modern Hebrew’) were predominantly Ashkenazi; as such, the graphemes that previously represented /q/ and /k/ are generally both realized as [k], and the graphemes for /h/ and /ʕ/ are pronounced as [χ] and [ʔ] respectively (Bentur 1978). The pharyngeal pronunciations are retained by some speakers of Yemenite and Mizrahi origin, who also generally realize the rhotic consonant as an alveolar trill rather than a uvular approximant, often known as the ‘Mizrahi’ and ‘Yemenite’ Modern Hebrew dialects (Asherov & Cohen 2019). While the language family of Modern Hebrew is usually defined as Semitic, other linguistic scholars consider its diverse influences to have formed an Indo-European and Semitic hybrid (Brown et al).

Israeli high schools devote a considerable amount of time to standardizing students’ grammar in writing and speech production, and this prescriptivism is embedded in the fabric of Hebrew-speaking communities. This quote from Matras & Schiff (2005) conveys the depth of such standardization initiatives:

‘[There is] a strong prescriptivist tradition in institutions such as the Hebrew Language Academy, the mainstream public media, the school system and the enormous establishment entrusted with teaching Hebrew as a foreign language. This attitude is also self-imposed by academic circles and Hebrew language departments...with educational measures aimed at safeguarding ‘correct’ pronunciation.’ (147)

The cultural and academic emphasis on grammatical correctness is derived not only from a desire to standardize the national language, but from the aforementioned Tiberian vocalization system and the various diasporic oral traditions that developed from it. Throughout the rabbinic Talmud, there are explicit lessons on how to pronounce certain sound segments in specific contexts (Mizrahi 2016). While not the focus of this paper, the potential impact of exposure to orthography and religious Jewish education on Modern Hebrew phonology will be explored later in Section 4.5.

1.2 Status of the Glottal Stop

The status of the glottal stop /ʔ/ in Modern Hebrew has been the subject of linguistic debate. /ʔ/ also incorporates the previous placement of the pharyngeal fricative /ʕ/, as the pronunciation of the grapheme that traditionally represented /ʕ/, *ayin*, has merged with that of *alef*, the grapheme for the glottal stop. /ʔ/ is never pronounced in codas and rarely elsewhere, which has led to the disintegration of certain minimal pairs such as [ha'raʁ] ‘the rabbit’ and [ʕa'raʁ] ‘Arabia’, now both /a'raʁ/ (Matras & Schiff 2005). Furthermore, Berman (1997) notes that the usage of glottal stops in onsets, the most common realization, is declining. Because of this phenomenon, Asherov & Cohen (2019) claims that the

occurrences of the glottal stop, which are rare in both cautious and typical speech, can be characterized as instances of insertion in order to rectify syllables without onsets. Similarly, Bentur (1978) attributes existing actualizations of the glottal stop to the influence of orthography and the Tiberian vocalization system, in which the glottal stop was phonemic and fully realized, on the revival of Modern Hebrew. Bentur asserts that given that /ʔ/ is ‘totally absent’ in verbs in informal speech, it is not underlying in verbal paradigms but appears in free variance.

Nonetheless, there is good reason to consider the glottal stop a part of Standard Modern Hebrew speakers’ phonemic inventory. In the *Encyclopedia of Hebrew Language and Linguistics*, Bolozsky observes that the glottal stop is occasionally used to assert distinctions in minimal pairs and in stressed syllables. For example, [am'arti qar'ʔa, 'lo qar'a] “I said ‘she read’, not ‘(she’s) cold’” (Bolozsky 2013). While the glottal stop is also used to reinforce strongly stressed syllables in languages such as English, in which /ʔ/ is not phonemic, the fact that its (optional) realization creates minimal pairs such as [qar'ʔa] ~ [qar'a] is evidence of its status as a phoneme in Modern Hebrew. Bolozsky also cites an experiment by Farrar & Hayon (1980) in which they ascertained that Modern Hebrew speakers posit underlying glottal stops even when they are not present phonetically. They propose that to do this, speakers use other phonetic cues such as length of vocalic nucleus in ʔVC syllables, variations in the pitch and amplitude of said vocalic nucleus, a period of laryngealization, and the length of the consonant before what would have been a glottal stop. Farrar & Hayon propose that these phonetic cues are allophones of a /ʔ/ phoneme (Farrar & Hayon 1980). By the same token, Rabin (1972) proposes that the omission of glottal stops and pharyngeals has led to the formation of two new vowel phonemes depending on whether the first or second vowel is stressed, as well as the insertion of glides [w] and [y] in certain contexts as in /ʃmu'ʕa/ > ʃmu'wa. These phenomena evidence the status of /ʔ/ as a phoneme, as the new vowels and glide insertions can be considered allophones.

1.3 Opaque Segholate Nouns

Modern Hebrew segholates are nouns with penultimate stress and an exceptional vowel pattern, named as such after the Biblical Hebrew vowel diacritic ‘seghol’, which represents /ε/. While most C-final nouns in Biblical Hebrew have final stress, Yeverchayahu & Bat-El (2020) attributes penultimate stress in segholates to the deletion of final vowels during the historical development of Pre-Hebrew into Biblical Hebrew (for example, /'dɪʃna/ ‘fat ashes’ became /'deʃen/).

Hebrew is non-concatenative with templatic morphology; noun and verb classes are composed of three-consonant roots inserted into templates that can be appended by affixes. An un-affixed word consists of three morphemes: the triconsonantal root (base morpheme), the vowel pattern, and the prosodic template (McCarthy 1981). Each noun class, or *mishkal*, has its own, distinct morphology that includes a set of configurations, inflectional paradigms (possessive forms, plural forms, etc.), and sometimes affixes. As such, Yeverchayahu & Bat-El (2020) ascribe the divergent stress patterns of segholate nouns to Co-phonology theory (Orgun 1996), an Optimality Theory analysis in which different classes of words have different constraint rankings.

Segholate nouns in Biblical Hebrew and Modern Hebrew are typically analyzed as having the prosodic template CVCC due to the structure of plurals and possessives in their inflectional paradigms. Morpho-phonological alternations such as [ʔzerem ~ zərɔm'im] are the reason this template is postulated, because there is no phonological motivation for the ε ~ ɔ alternation (Yeverchayahu & Bat-El 2020). As such, the plurals are usually analyzed as having the template CVCɔC, and the singular and possessive forms start as CVCC and surface according to the phonotactic constraints of the language.

This analysis breaks down when it comes to segholate nouns with the triconsonantal root C-C-ʔ. The singular forms of these nouns are opaque in Modern Hebrew due to phonological constraints that prohibit certain consonant clusters and delete /ʔ/ at the end of a word. For example, the Modern Hebrew noun [ˈdeʃe] ‘lawn’ or ‘grass’ is usually analyzed using the following derivation:

UR: /deʃʔ/
Vowel Epenthesis: deʃeʔ
ʔ-Deletion: deʃe
SR: deʃe

This derivation is opaque, as the reason for [e] insertion is not apparent based on the surface form [ˈdeʃe]. Speakers need to somehow posit the intermediate form [deʃeʔ] in order to relate the input and non-faithful output (McCarthy 1999). As with [ˈzerem], the inflectional paradigm for this noun includes the plural [deʃaˈʔot] ‘lawns’ and possessive [diʃˈʔo] ‘his lawn’, which has led to the traditional analysis of a CVCC underlying representation shown above. It is important to note that the pronunciation of /ʔ/ in the plural and possessive inflectional forms of the segholates is rare and optional; [deʃaˈʔot] ‘lawns’ sometimes surfaces as [deʃaˈot] (Asherov & Cohen 2019). Given that the underlying /ʔ/ never surfaces in the singular form [ˈdeʃe], how do speakers psychologically access the glottal stop to produce the plural and possessive inflections?

There are several different analyses proposed to account for these opaque segholate noun paradigms. Yeverechyahu & Bat-El (2020) assert that the prosodic template for Biblical Hebrew segholate nouns is not CVCC, as previously assumed, but CVCVC, and the CVCʔC plurals and CVCC possessives are just ‘lexically specific configurations’ for plurals and possessives in segholate inflectional paradigms. This means that the input for Modern Hebrew [ˈdeʃe] is actually /deʃeʔ/, leading to a transparent derivation in which the word-final glottal stop is deleted. Sympathy Theory (McCarthy 1999) can also account for this data, proposing that there exists a selector constraint MAX_V that selects for faithfulness violations between the output and a ‘failed’ or ‘sympathetic’ candidate, which in this case is [ˈdeʃeʔ]. The winning candidate [ˈdeʃe] is influenced not only by the input /deʃeʔ/, but by an obligation to remain faithful to the sympathetic candidate [ˈdeʃeʔ], thus realizing the epenthesis vowel [e]. It is also possible that the glottal stop is not underlying in the segholates, but rather a segment inserted as a result of a productive rule to ‘repair[s] onsetless syllables’ in the plural and possessive inflections (Asherov & Cohen 2019).

Finally, as discussed in Section 1.2, the phonemic status of the glottal stop in Modern Hebrew is debatable. The modern realization of the glottal stop in the plural and possessive segholate inflections may not be the result of a productive phonological process; rather, these forms may be a memorized group of lexically specific configurations.

1.4 Guttural-Final Transparent Verb Paradigms

Modern Hebrew verbs with triconsonantal roots are inflected based on gender and number in the present and imperative tense, and additionally inflected for person in past and future forms (Sumner 2003). According to Sumner (2003), these three consonants are always pronounced and written orthographically. However, for verbs with the triconsonantal root C-C-ʔ, the final /ʔ/ is not phonetically realized in all conjugations. For example, the verb /likro/ ‘to read’, has the triconsonantal root k-r-ʔ. The past-tense, third-person, masculine singular form (hereafter ‘3ms’) [karˈa] ‘[he] healed’ forms a minimal pair with the past-tense, third-person, feminine singular form (hereafter ‘3fs’) [karˈʔa] ‘[she]

healed.’ In typical Modern Hebrew verb paradigms, the 3ms form ends with the third root consonant. Modern Hebrew never realizes /ʔ/ in codas; therefore, the final glottal stops in 3ms forms of C-C-ʔ verbs are deleted.

Per Section 1.2, all realizations of [ʔ] are rare and optional in Modern Hebrew, leading to the disintegration of these minimal pairs. However, an experiment by Semiloff-Zelasko (1975) found strong evidence for the phonemic status of glottal stops in these C-C-ʔ verbs; even if the /ʔ/ in 3fs forms is not phonetically present, speakers still use other phonetic cues such as laryngealization and the duration of the medial root consonant to designate a verb form as feminine or masculine. As in Farrar & Hayon (1980), the laryngealization period and shortening of the medial consonant may function as allophones of the underlying glottal stop.

2 Novel Words and Phonological Abstractness

2.1 Productive vs. Idiosyncratic Alternations

The realization of borrowed and novel words by speakers of a language provides insight into speakers’ knowledge of the phonotactics of their language. These new words are typically changed to conform to the speakers’ phonemic inventory, and the ways they are produced can reveal the extent to which a morphophonemic alternation is memorized or stored as a productive, systematic rule (Berko 1958). An alternation is the result of a productive rule if the rule applies wherever the structural description is met.

Bolozsky (2009) cites the phenomenon of Modern Hebrew spirantization, in which underlying stop consonants alternate with fricatives after vowels, as an example of an alternation that is memorized rather than productive. He claims that due to the merging of certain stop phonemes in Modern Hebrew, this process is not productive but rather an idiosyncratic ‘generalization’ made by speakers based on the frequency at which these fricatives appear in specific surface contexts. Bentur (1978) similarly notes that, for example, the underlying /k/ represented orthographically as כ *kaf* alternates with the fricative /x/ represented orthographically as ח *khaf*, while the underlying /k/ represented by the grapheme ק *qof*, which was once /q/, does not undergo spirantization (Bentur, 25). In other words, spirantization does not apply every time the structural description is met (underlying /k/ following a vowel), but only when the underlying /k/ is represented orthographically as כ *kaf*. As such, Bolozsky proposes that second language learners of Hebrew should not be taught about spirantization as a ‘pseudo-phonetic process’, but as an individually memorized class of exceptions (Bolozsky 2009).

Along the same vein, Semiloff-Zelasko (1975) maintains that the phonemic status of both the glottal stop and the pharyngeal fricative /ʕ/ are retained in Modern Hebrew phonology because different phonological rules are applied to the contexts in which they appear underlyingly. Both Mizrahi Modern Hebrew (see Section 1.1) and Biblical Hebrew apply the historical rule of lowering to non-low vowels before word-final pharyngeal consonants. These distinctions are preserved in surface realizations by speakers of Standard Modern Hebrew: ‘know (ms)’ is [jodea] due to the historical presence of word-final /ʕ/, while ‘read (ms)’ is [kore] due to the word-final /ʔ/. However, Bolozsky (2009) places these distinctions in the same class of idiosyncratic, memorized exceptions as spirantized obstruents. Classifying these phenomena as memorized rather than productive means that one would expect loan or novel words to not exhibit spirantization when obstruents come before vowels, or lowering when non-low vowels occur at the ends of words before neutralized pharyngeals.

2.2 The Example of Dutch Neutralized Voicing

In *Predicting the Unpredictable: Interpreting Neutralized Segments in Dutch*, Mirjam Ernestus and R. Harald Baayen conducted a production task with the goal of understanding how speakers assign underlying representations to segments in neutralizing positions. Just as /ʔ/ is neutralized in the singular forms of Modern Hebrew segholates, the voicing specification for word-final obstruents is nondistinctive in Dutch. Obstruents are voiced in Dutch before voiced stops, and voiceless elsewhere. This leads to the dissolution of minimal pairs when [t] and [d] both appear at the ends of words, as in the following example:

verwijd niet → [verweit nit] ‘widen not’
verwijt niet → [verweit nit] ‘reproach not’

The only way a Dutch speaker would know that [verweit nit] has an underlying /d/ is if they also know the morphologically related form [verveiden]. Ernestus & Baayen (2003) presented Dutch speakers with novel words ending in obstruents that were neutralized for voice in an attempt to understand the strategy with which speakers posit underlying forms for abstract segments. They propose four potential strategies:

- (1) Speakers assume that underlying forms are the same as surface forms. If they hear a voiced obstruent, they interpret its underlying representation to be voiced as well.
- (2) Speakers randomly assign underlying forms; they will choose [+voice] for ½ of the novel underlying forms, and the other ½ will be underlyingly [-voice].
- (3) Speakers decide underlying forms based on whichever phoneme is less marked in the phonology of their language; if the voiced variant has a stronger position in the phonology, speakers will posit a majority of the novel underlying forms to be voiced.
- (4) Speakers decide underlying forms based on the distribution of voiced and voiceless underlying forms among existing, phonologically similar morphemes in the language; they will assign voicing based on the voicing shared by similar words in the lexicon.

Ernestus & Baayen (2003) found Hypothesis (4) to be true for their participants: the percentage of participants that selected voiceless underlying representations was proportional to the percentage of phonologically similar existing words with voiceless-final underlying obstruents. For example, the word [marx] was interpreted as /mary/ by all of the participants, because nearly all word-final velar fricatives in Dutch are underlyingly voiced.

It is important to note that the phenomenon of neutralized, word-final glottal stops in Modern Hebrew may have a different explanation. While all Dutch stops have a voiced and voiceless phoneme, and therefore speakers posit underlying stops for all stop-final words with neutralized voicing, there is a possibility that speakers do not posit underlying final glottal stops in the Hebrew segholates, and that surface realizations of glottal stops in the plural and possessive forms are simply the result of a productive process to provide an onset between two vowels (see Section 1.3).

2.3 Evaluating the Hypotheses of Sumner (2003)

In *A psycholinguistic approach to abstractness: The case of Hebrew*, Meghan Sumner attempts to analyse how speakers conceive of glottal stops in Modern Hebrew opaque segholate singular forms and

transparent 3fs verb forms through proposing three hypotheses. The first is an ‘abstract’ analysis in which all segholate inflections come from the traditional input CVCC, as in /deʃʔ/, and all verb inflections also contain an underlying /ʔ/ as in /karaʔ/. The second, ‘concrete’ analysis states that while all transparent verb inflections contain an underlying /ʔ/, speakers are unable to access an underlying /ʔ/ in the opaque segholate singular forms. This ‘concrete’ explanation posits two separate underlying forms for the singular and possessive/plural forms of segholates; i.e., [ˈdeʃe] ‘lawn’ is underlyingly /deʃe/, while [diʃˈʔo] ‘his lawn’ is underlyingly /deʃʔ/. Note that in this paper, I will proceed with the assumption that all words in an inflectional paradigm have the same underlying representation.

The third hypothesis proposes that the noun and verb forms in which a glottal stop is surface-realized are not the result of a productive process, and the respective surface representations of these forms are equivalent to their underlying representations (Sumner 2003). This would mean that the underlying form of both [deʃe] ‘lawn’ and [diʃˈʔo] ‘his lawn’ is /deʃe/, and the phonetic realization of /ʔ/ in [diʃˈʔo] is memorized by speakers.

Sumner conducted a phonological priming experiment with an auditory lexical decision task in order to test whether speakers experience phonological priming when noun or verb forms proposed to have an underlying glottal stop (but realized without the glottal stop) precede words with pronounced glottal stops. She tested three subject groups: literate adult speakers, literate teenage speakers of Modern Hebrew, and illiterate adult speakers, and found that while all three experienced some degree of priming, both the teenage literate speakers and the illiterate adult speakers exhibited less priming than the literate adults. This suggests both a potential influence of orthography on speaker’s phonemic inventories and a generational decline in phonetic realizations of the glottal stop.

3 Method: Elicitation Task

3.1 Research Questions

My research attempts to address two main questions: (1) What is the status of the glottal stop in the phonological inventories of Modern Hebrew speakers? (2) How do native speakers of Modern Hebrew interpret the underlying forms of /ʔ/-final segholate nouns? These questions follow from the previous experiments by Sumner (2003) and Ernestus & Baayen (2003) discussed in Section 2.

I conducted an elicitation task with four native speakers of Modern Hebrew. I first constructed ten (10) novel, triconsonantal, /ʔ/-final roots, and converted each into two (2) novel words: one singular segholate noun and one infinitive verb. The segholate noun forms followed the CeCe template of [ˈdeʃe] ‘lawn’, and the infinitive verb forms followed the CeCaCe template of [lɛraˈpe] ‘to heal’. Four native speakers of Modern Hebrew listened to recordings of five novel singular segholate nouns and five novel infinitive verbs. The recordings were of another native speaker, who produced ten novel singular segholate nouns and ten novel infinitive verbs within novel carrier sentences. These speakers were then provided with further carrier sentences that required them to produce the plural forms for the segholate nouns, and the 3ms and 3fs forms for the verbs in order to fill in a blank space within the sentence. Examples will be provided in Sections 3.3.2 and 3.3.3. Participant responses were all recorded in a small, empty classroom on a laptop using Praat software (Boersma & Weenink 2022) and analyzed for the realization of glottal stops.

All participants were volunteers. While the speaker who produced the experimental stimuli was female, the four participants were all male. This gender difference was not intentional; due to time constraints and difficulty in recruitment, I was only able to control for the age range (18-31 years old).

This was the main and only study I conducted on this topic; however, given the small scale and possibility for further work (see Section 4), this investigation could serve as a pilot study for future experiments.

3.2 Hypotheses

There are three possible hypotheses for this experiment. In this section, I outline each potential outcome and its implications. I predict that one of the following is true:

- (1) The glottal stop retains its status as a full phoneme in Modern Hebrew, and speakers require a triconsonantal root for both nouns and verbs.
- (2) The glottal stop retains its status as a full phoneme in Modern Hebrew, and speakers require a triconsonantal root for verbs but not for nouns.
- (3) The glottal stop is not a full phoneme in Modern Hebrew, and speakers do not require a triconsonantal root for verbs or nouns.

Hypothesis (1) predicts that speakers will produce glottal stops for all/the majority of the 3fs verbs, and all/the majority of the plural segholate nouns. This outcome implies that when speakers hear the singular segholate noun ['defe] 'lawn', they posit an underlying final glottal stop. Given that the novel nouns were all phonologically similar to the existing morpheme ['defe] 'lawn', and the verb forms were all phonologically similar to the existing morpheme [lera'pe] 'to heal', this outcome is the most similar to Hypothesis (4) in Ernestus & Baayen (2003), which states that speakers assign underlying forms based on the distributions of phonologically similar words in their mental lexicons.

Hypothesis (2) predicts that speakers will produce glottal stops for all/the majority of the 3fs verbs, but a minority/none of the plural segholate nouns. This outcome implies that when speakers hear the singular segholate noun ['defe] 'lawn', they do not assume an underlying final glottal stop. It further suggests that the existing realizations of glottal stops in the plural and possessive segholate forms, such as [defa'ʔot] 'lawns', are either (a) not the result of a productive rule but rather a memorized group of exceptions, or (b) the result of a productive process to provide syllable onsets (see Section 1.3). The analysis that speakers require a triconsonantal root for verbs but not nouns is supported by Sumner (2002), which states that while borrowed verbs have to adapt into one of the seven templatic verb class patterns (known as *binyanim*), borrowed/new nouns do not necessarily adhere to existing patterns.

Hypothesis (3) predicts that speakers will produce glottal stops for a minority/none of the 3fs verbs and a minority/none of the plural segholate nouns. This outcome implies that when speakers hear the infinitive verb [lera'pe] 'to heal', they do not assume an underlying final glottal stop. Additionally, as in hypothesis (2), they do not assume an underlying final glottal stop for ['defe] 'lawn'. It further suggests that the existing realizations of glottal stops in 3fs verbs, such as [rip'ʔa] '[she] healed', as well as the existing realizations of glottal stops in the plural and possessive segholates, such as [defa'ʔot] 'lawns', are either (a) not the result of a productive rule but rather a memorized group of exceptions, or (b) the result of a productive process to provide onsets (see Section 1.3). This is the least likely outcome, as the triconsonantal template is generally accepted as obligatory for Modern Hebrew verbs.

3.3 Procedure

I first constructed ten novel C-C-ʔ roots and turned each into one infinitive verb and one segholate singular noun. Specifically, each triconsonantal root ended in the letter א *alef*, which historically

represented /ʔ/. Each verb had the vocalic pattern CaCe as in [lerape] ‘to heal’, and each noun had the vocalic pattern CeCe as in [deʃe] ‘lawn’ (see Table 1 for novel nouns; Table 2 for novel verbs).

A 22-year-old female, adult, native Modern Hebrew speaker was recorded producing all ten verbs and nouns. For each novel verb, the speaker was recorded saying the sentence ‘I want [infinitive V]’. For each novel noun, the speaker recorded the sentence ‘The [singular N] is green’. The non-participant speaker was also recorded producing the same two constructions with the existing noun [deʃe] and existing verb [lerape], which serve as controls. Participants were asked to produce the plural forms of the segholate nouns, and then the 3ms and 3fs forms of the verbs. Each participant received five novel segholate nouns and five novel verbs so that each novel C-C-ʔ root was tested twice as a noun and twice as a verb. Participant responses were recorded using Praat software.

Table 1: *Novel Nouns in Elicitation Task*

/CeCeʔ/ Uninflected
/ʃetseʔ/
/ʃezeʔ/
/tetseʔ/
/peneʔ/
/ʃekeʔ/
/zeʃeʔ/
/seʃeʔ/
/geteʔ/
/regeʔ/
/ʃegeʔ/

Table 2: *Novel Verbs in Elicitation Task*

/CaCeʔ/ Infinitive	Past, Sg Masc	Past, Sg Fem
/lefʔatseʔ/	/ʃitsa/	/ʃitsʔa/
/lefʔazeʔ/	/ʃiza/	/ʃizʔa/
/letʔatseʔ/	/titsa/	/titsʔa/
/lepʔaneʔ/	/pina/	/pinʔa/
/lefʔakeʔ/	/ʃika/	/ʃikʔa/
/lezaʔfeʔ/	/ziʃa/	/ziʃʔa/
/lesaʔfeʔ/	/siʃa/	/siʃʔa/
/legʔateʔ/	/gita/	/gitʔa/
/lerʔageʔ/	/riga/	/rigʔa/
/lefʔageʔ/	/ʃiga/	/ʃigʔa/

3.3.1 Participants

There were four participants between 18-31 years old, all men and all native speakers of Modern Hebrew. Two participants had lived their entire lives in Israel, and crucially, went through formal

secondary education in Hebrew in Israeli high schools. The other two participants were both born in Israel and moved to the U.S. before the age of twelve; therefore, they experienced most of their formal education in English in the U.S.

Bentur (1978) attributes the realization of guttural consonants in Modern Hebrew to morphophonemic alternations that are orthographically encoded due to historical changes, but not the result of productive rules. She proposes that C-C-ʔ verbs in Modern Hebrew actually have biradical C-C roots, and the /ʔ/ is inserted in free variance due to the influence of orthography and speakers' exposure to Biblical Hebrew (see Section 1.1). While this was not the focus of my study, I was interested to see if I would observe any differences in the way the participants who attended high school in Israel produced glottal stops in both the nouns and verbs compared to those who went to high school in the U.S. I noted participants' self-reported levels of religious education for this same reason. Participants were asked to self-identify with respect to religious levels, but this measurement typically includes both formal religious schooling and family observance of Judaism. As stated above, this information is not the central focus of my study and thus can be found in Appendix 1.

3.3.2 *Novel Nouns*

Each participant first listened to the speaker produce the sentences 'The lawn is green. The __ are green' in Hebrew. I then asked them to fill in the blank in the second sentence with the plural form for 'lawn'. The segholate, singular noun, [ʔdeʃe] 'lawn', was pronounced in the first sentence. The adjective [jiru'kim] 'green' in the second sentence was masculine and plural, indicating that the elicited plural form should be masculine and plural. While [ʔdeʃe] is typically pluralized with a feminine suffix, as in [deʃa'ʔot], I requested a masculine plural form because this is the default for Hebrew speakers pronouncing novel nouns without prior knowledge of grammatical gender (Berent et al. 1999). As with the verbs, the plural forms were in medial position in each sentence so that their production would not be isolated, and therefore more informal.

After providing the existing singular form example, which served as a control, I gave two more novel noun examples so that participants would understand how to respond. These two examples were drawn from the five novel noun forms that the participant did not receive. After the examples, I conducted this same elicitation task for five nouns. Table 3 provides a sample elicitation task using the existing control noun:

Table 3: *Sample Noun Elicitation Task*

Novel Noun (Uninflected)	Non-Participant Speaker Recording	Elicited Sentences	Participant Response
(1) [ʔdeʃe] 'Lawn.'	[ha'ʔdeʃe jarok] 'The lawn is green.'	[ha __ jiru'kim] 'The __ are green.'	[hadeʃa'ʔim jiru'kim] 'The lawns are green.'

3.3.3 *Novel Verbs*

Each participant first listened to the recorded speaker produce the sentence 'I want [to heal]' in Hebrew'. I then elicited the 3ms and 3fs forms of [lera'pe] 'to heal' by asking the participant to fill in the blank in the Hebrew sentences: 'Yesterday, he __. Yesterday, she __'. The verbs were placed in the final

position of each sentence so that their production would not be isolated, and therefore more natural and conversational.

Following the existing verb example, I then provided each participant with two example novel verbs so that they would understand how to respond. Just as with the noun task, these were drawn from the five novel verb forms that the participant did not receive. After the two examples, I conducted this same elicitation task for five verbs. Table 4 below provides a sample elicitation task using the existing control verb:

Table 4: *Sample Verb Elicitation Task*

Example Verb (Infinitive)	Non-Participant Speaker Recording	Elicited Sentences	Participant Response
[lera'pe] 'To heal.'	[a'ni ro'tse lera'pe] 'I want to heal.'	[et'mol 'hu __] 'Yesterday, he __.'	[et'mol 'hu ri'pa] 'Yesterday, he healed.'
		[et'mol 'hi __] 'Yesterday, she __.'	[et'mol 'hi rip'ʔa] 'Yesterday, she healed.'

4 Results and Discussion

4.1 Defining Glottal Stops

The glottal stop /ʔ/ is produced by closing the vocal folds and entirely obstructing airflow in the glottal tract. Farrar & Hayon (1980) found that other phonetic cues, such as a period of laryngealization or irregular voicing, may also constitute allophonic realizations of glottal stops for Modern Hebrew speakers.

On a waveform, voicing irregularity between vowels is indicated by a sudden decrease in amplitude, while on a spectrogram, this can be seen through an irregular voicing bar and the disappearance of formants. The four participants produced periods of irregularity of varying durations, and I divided these durations arbitrarily into three main categories: irregular periods that lasted between 0 and 0.01 seconds were defined as having no glottalization; irregular periods between 0.01 and 0.05 seconds were defined as glottalization; and irregular periods lasting more than 0.05 were defined as full glottal stops. Figures 1, 2, and 3 respectively, provide examples of each category.

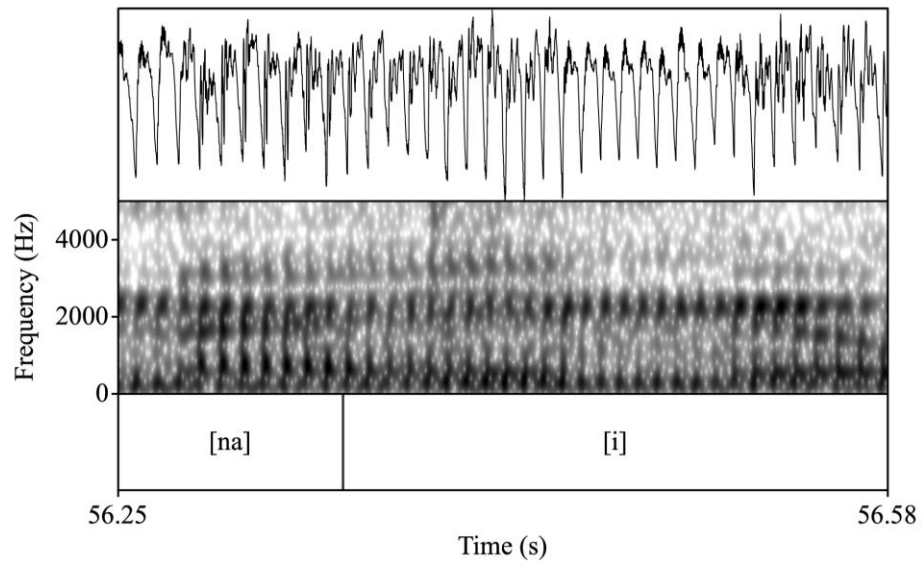


Figure 1: NO GLOTTAL; Participant 1; Noun 4; [pena'im].

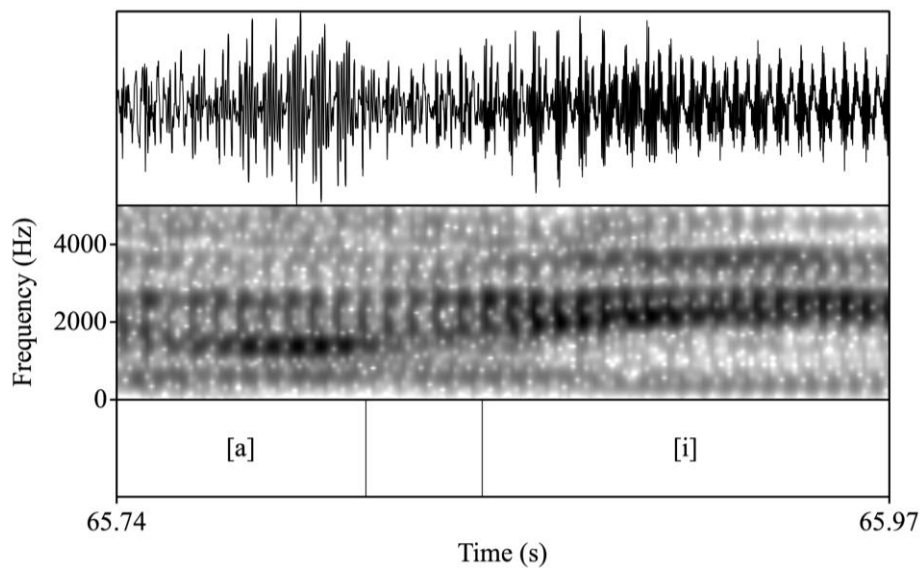


Figure 2: GLOTTALIZATION; Participant 2; Noun 6; [zeʔa'im].

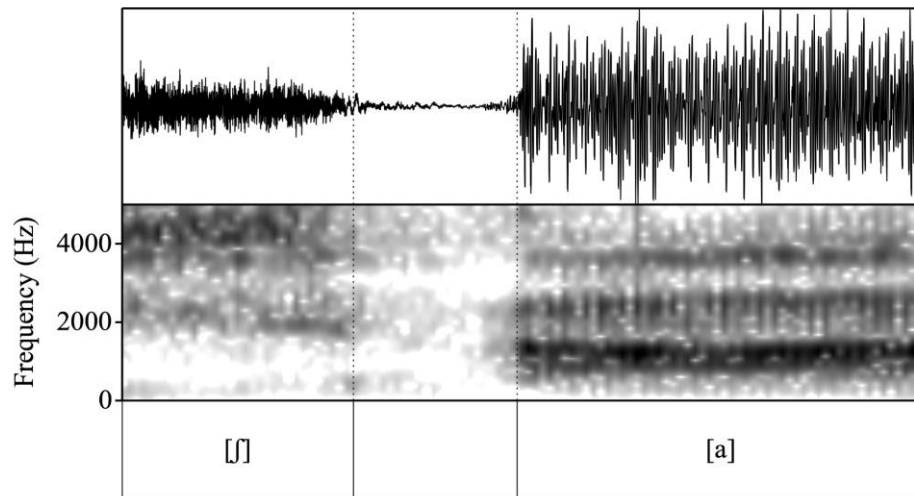


Figure 3: *FULL GLOTTAL STOP; Participant 2; Verb 7; [siʔa].*

4.2 Noun Results

For the control segholate plural [deʃaʔot] ‘lawns’, two participants produced full glottal stops, and two participants produced a period of glottalization. Therefore, for the control plural form, all participants posited a final, third consonant. This serves as an important point of comparison for the novel plural forms.

There were twenty (20) productions of the ten novel segholate nouns. Of these twenty productions, seven (7) were classified as having no glottalization; eight (8) were classified as producing glottalization; and five (5) were categorized as full glottal stops. In other words, of the twenty possible instances for glottal stops to occur, full glottal stops were only realized 25% of the time. Glottalization was the most common realization at 40%, followed by no glottalization at 35%. These results are shown in Table 5 below:

Table 5: *Results for Each Novel Noun*

Singular Noun	No Glottal	Glottalization	Full Glottal Stop
[deʃe] (control)		2	2
1. [ʃetse]			2
2. [ʃeze]	1	1	
3. [tetse]	1		1
4. [pene]	1	1	
5. [ʃeke]		1	1

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6. [zeʔe]		2	
7. [seʔe]	2		
8. [gete]	1	1	
9. [rege]	1	1	
10. [ʔege]		1	1

These results also varied slightly depending on the background of each participant. This is purely a numerical observation; statistical tests would not yield results due to the small sample size. Participants 2 and 4, who experienced all of their formal education in Israel, produced either a full glottal stop or a glottalization period for 70% of the novel plural nouns. Participants 3 and 4, who both attended high school (and beyond) in the United States, produced either a full glottal stop or a glottalization period for 60% of the novel 3fs verbs.

Further, the realization of a glottalization period appears to be arbitrary and not based on the preceding consonant. Each novel plural form was elicited from two participants; nouns (1) through (5) were given to Participants 1 and 4, and nouns (6) through (10) were given to Participants 2 and 3. There does not appear to be consistency between the results of Participants 1 and 4, or the results of Participants 2 and 3, which suggests that speakers produced glottal stops at random and not based on phonological context. Table 6 below displays the novel noun results for each participant.

Table 6: *Noun Results by Participant Background*

Singular Noun	Participant 1 U.S. High School Strong religious background	Participant 2 Israeli High School Strong religious background	Participant 3 U.S. High School Less religious background	Participant 4 Israeli High School No religious background
[deʔe] (control)	Full Glottal	Glottalization	Full Glottal	Glottalization
1. [ʔetse]	Full Glottal	—	—	Full Glottal
2. [ʔeze]	None	—	—	Glottalization
3. [tetse]	None	—	—	Full Glottal
4. [pene]	None	—	—	Glottalization
5. [ʔeke]	Full Glottal	—	—	Glottalization
6. [zeʔe]	—	Glottalization	Glottalization	
7. [seʔe]	—	None	None	

8. [gete]	—	None	Glottalization	
9. [rege]	—	None	Glottalization	
10. [ʃege]	—	Glottalization	Full Glottal	

4.3 Verb Results

For the control 3fs verb form [rip'ʔa] 'she healed', two participants produced full glottal stops, and two participants realized a period of glottalization. Therefore, for the control 3fs form, all participants posited a final, third consonant. This serves as an important point of comparison for the novel plural forms.

All participants assumed a final, third consonant for all of the novel 3fs verbs. Of the twenty (20) productions of novel 3fs verb forms, none were produced without either glottalization or the insertion of another consonant where the glottal stop would have been. One (1) realized a glottalization period, and four (4) produced a full glottal stop. The other fifteen (15) novel forms were produced with the insertion of the consonant [t] where the glottal stop was expected. This means that 0% of the productions had no glottalization or [t] insertion; 5% exhibited glottalization; 20% realized full glottal stops; and 75% showed [t] insertion. The instances of [t] insertion will be analyzed further in Section 4.4.

If we ignore the fifteen (15) instances of [t] insertion, of the five (5) non-insertion cases, four (4) realized a full glottal stop and one (1) resulted in glottalization. This alone is telling: there were no instances of a novel 3fs verb form without three consonants, and a full glottal stop is the preferred realization of an underlying glottal stop (as opposed to glottalization, which was preferred for the nouns). These results are displayed in Table 7 below:

Table 7: Results for Each Novel Verb

Infinitive Verb	No Glottal	Glottalization	Full Glottal Stop	[t] Insertion
[lerape] (control)		2	2	
1. [leʃat̪se]				2
2. [leʃaze]				2
3. [letat̪se]		1		1
4. [lep̪ane]				2
5. [leʃake]			1	1
6. [lezaf̪e]			1	1
7. [lesaf̪e]			1	1
8. [legate]				2

9. [lerage]			1	1
10. [leʃage]				2

As with the nouns, the results for the U.S.-educated and Israel-educated participants varied. Between the ten (10) total productions by Participants 1 and 3, who were educated in the U.S., one (1) was a full glottal stop and one (1) resulted in glottalization. Between the ten (10) total productions by Participants 2 and 4, who were educated in Israel, three (3) were full glottal stops and one (1) resulted in glottalization. Unsurprisingly, the participants educated in Israel produced more glottal stops in the novel 3fs verb forms. Table 8 below displays the novel verb results for each participant.

Table 8: *Verb Results by Participant Background*

Infinitive Verb	Participant 1 U.S. High School Strong religious background	Participant 2 Israeli High School Strong religious background	Participant 3 U.S. High School Less religious background	Participant 4 Israeli High School No religious background
[lerape] (control)	Full Glottal	Glottalization	Full Glottal	Glottalization
1. [leʃatse]	[t]			[t]
2. [leʃaze]	[t]			[t]
3. [letatse]	[t]		Glottalization	
4. [lepane]	[t]			[t]
5. [leʃake]	Full Glottal			[t]
6. [lezaʃe]		Full Glottal	[t]	
7. [lesaʃe]		Full Glottal	[t]	
8. [legate]		[t]		[t]
9. [lerage]		Full Glottal	[t]	
10. [leʃage]		[t]	[t]	

4.4 Epenthetic [t]

As stated above, 75% of the twenty (20) total novel verb productions realized the insertion of [t] where the final glottal stop was expected. An example waveform for [t] insertion is shown in Figure 4:

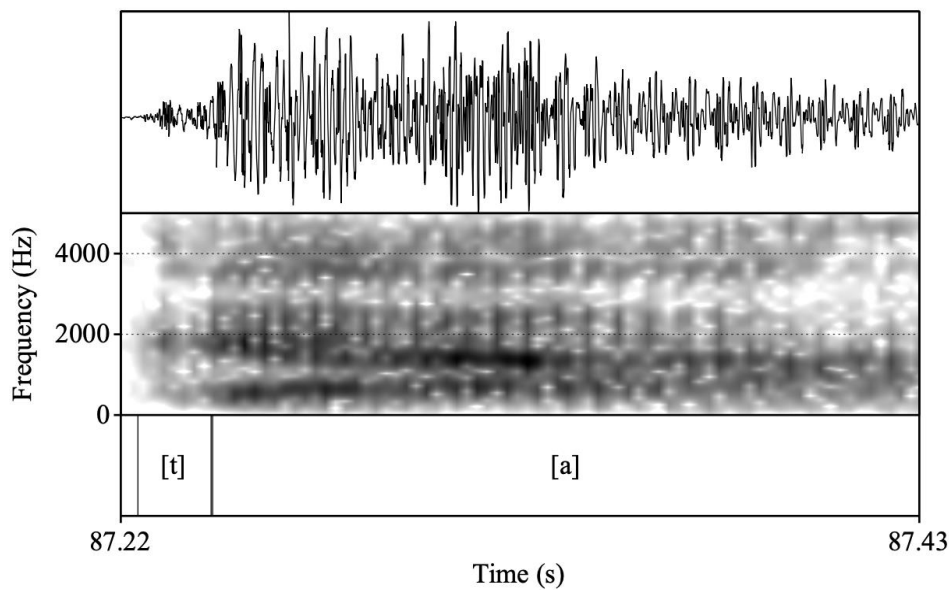


Figure 4: *[t] Insertion; Participant 2; Verb 8; [gite'ta].*

It is important to note that there does not appear to be a specific phonological context (for example, the preceding consonant) that determined when speakers inserted [t]. Different speakers made different assumptions regarding the underlying forms of the same novel verbs. For example, Participant 2 pronounced the 3fs form of novel verb 9 as [rig'ʔa], with a full glottal stop, while Participant 3 pronounced the same 3fs form as [rig'ta], with epenthetic [t]. Novel verbs 3, 5, 6, 7, and 9 each had one speaker choose to insert [t], and one speaker choose to produce glottalization or a full glottal stop. The fact that five (5) out of ten (10) novel verb forms exhibited diverging results with respect to how speakers choose to analyse them indicates that epenthetic [t] is not limited to a specific phonological environment.

The most likely explanation for [t] insertion in the 3fs verbs is that speakers posited an underlying final /j/ instead of final /ʔ/ or a biradical C-C root. There are certain verb templates that insert [-t] in 3fs forms as a part of their inflectional morphology. Weak verbs (verbs with final root consonants that are not surface realized in certain paradigms) with final root consonant 'yod exhibit obligatory [t] insertion in the 3fs form. For example, the verb /lena'kot/ 'to clean' has the triconsonantal root n-k-j. The singular, masculine, past-tense form is [nik'a] '[he] cleaned', while the feminine is [nik'ta] '[she] cleaned' (Sumner 2002).

According to Berman (1981), children natively acquiring Modern Hebrew overapply this [t] insertion to words that are historically root-final /ʕ/, now merged with /ʔ/. For example, the verb for 'to swallow' has the triconsonantal root b-l-ʕ. While the 'correct' 3fs form is [bal'ʔa] '[she] swallowed', children frequently pronounce it as [bal'ta] instead. Berman interprets this non-normative usage as children processing these 'defective' inflections in which the final consonant is elided as still being triconsonantal, and notes that high school Hebrew grammar classes are actively trying to 'eradicate' these common, deviant patterns.

This phenomenon likely explains the instances of [t] insertion produced by the participants. This is in line with my results; Participant 3, who was educated in the U.S. (and whose grandmother is a Hebrew teacher), initially produced the control 3fs form for [lera'pe] 'to heal' as [rip'ta]. While he

changed his response to [rip'ʔa] after some deliberation, this indicates that there is some ambiguity as to whether speakers posit final /ʔ/, even in existing verbs. He later asked whether the verb root for novel verb 9 [lera'ge] ended with an *ayin* before answering. I did not give a response, but he insisted that this knowledge changes whether the novel 3fs form is [rig'ta] (if *ayin*) or [rig'ʔa] (if *alef*).

Speakers assumed final /j/ rather than /ʔ/ when they heard the infinitive novel verbs either because /j/-final verb roots are more common than /ʔ/-final in Hebrew, or because speakers find it easier to pronounce epenthetic [t] than [ʔ] in onsets. Regardless, these results illuminate participants' reluctance to posit a glottal stop as the final consonant in verb forms.

4.5 Hypotheses Revisited

I have slightly revised the predictions made by my three hypotheses to account for the widespread phenomenon of [t] insertion in the novel 3fs verbs. Given that the [t] insertion is likely a result of speakers preferring underlying final /j/ to underlying final /ʔ/ in verb roots (see Section 4.4), these revisions do not change the significance of each potential outcome with respect to speakers' preferences for a triconsonantal root in Modern Hebrew.

- (1) The glottal stop retains its status as a full phoneme in Modern Hebrew, and speakers require a triconsonantal root for both nouns and verbs.
- (2) The glottal stop retains its status as a full phoneme in Modern Hebrew, and speakers require a triconsonantal root for verbs but not for nouns.
- (3) The glottal stop is not a full phoneme in Modern Hebrew, and speakers do not require a triconsonantal root for verbs or nouns.

I found hypothesis (2) to be the most true; there is definitely a discrepancy in participants' capacity to deduce underlying final consonants in the /ʔ/-final verbs compared to the /ʔ/-final segholate nouns. The results indicate that while speakers still prefer a three-consonant root for both verbs and nouns, their preference may be significantly weaker for nouns. When speakers do posit underlying final /ʔ/, they prefer to realize it as a glottalization period in nouns and a full glottal stop in verbs. Additionally, speakers appear reluctant to posit final /ʔ/ in the obligatorily triconsonantal verbs, preferring to assume underlying final /j/ instead.

Speakers assumed that 35% of the novel plural nouns did not have a third consonant, compared to none of the novel 3fs verbs. This demonstrates a clear disparity in the strength of speakers' requirement for a triconsonantal root between nouns and verbs, as predicted by hypothesis (2). These results are illustrated in Table 9 below:

Table 9: *Overall Noun and Verb Results*

Outcome	Novel Plural Nouns	Novel 3fs Verbs
Full Glottal Stop or Epenthetic [t]	25%	95%
Glottalization Period	40%	5%
No Glottal Stop or Epenthetic [t]	35%	0%

While a majority of the novel plural nouns were realized with either a full glottal stop or a glottalization period (thus qualifying as a third consonant), 65% is a significantly weaker majority than the 100% outcome for the verbs. Additionally, it is worth noting the discrepancy in how posited underlying glottal stops were surface-realized between the nouns and verbs: 40% of speakers produced a glottalization period instead of a glottal stop in the plural nouns, compared to 5% of the 3fs verbs. As discussed in Section 4.3, of the five (5) verbs that did not exhibit epenthetic [t], four (4) were realized with a full glottal stop rather than glottalization. I have assumed that a glottalization period functions as an allophone of an underlying glottal stop in Hebrew (Farrar & Hayon 1980); however, it is still important to acknowledge this stark contrast.

4.5.1 *Impact of Orthography*

Given that Bentur (1978) asserts that access to orthography has an impact on Modern Hebrew speakers' linguistics knowledge and that /ʔ/-final verbs in Modern Hebrew actually have biradical C-C roots, I wanted to test whether participants who have had more contact with Hebrew orthography and grammatical prescriptivism in the classroom would produce more glottal stops (see Section 1.1). According to Bentur, participants should demonstrate a preference for a triconsonantal root in the novel verb forms, and the participants who attended Israeli high schools should assume underlying glottal stops more often (see Section 1.1).

Israel-educated participants did appear to assume underlying final /ʔ/ more often in both nouns and verbs. While both subject groups always assumed a triconsonantal root in verb forms, the U.S.-educated participants accepted a two-consonant root in nouns 40% of the time, compared to 30% for those educated in Israel. The difference in glottal stop production (10% for both nouns and verbs) is very slim; however, the U.S.-educated participants both still had significant access to Hebrew orthography.

Participant 3 went to high school in the U.S., but his grandmother is a Hebrew language teacher, and Participant 1, who also went to high school in the U.S., frequently reads novels in Hebrew. A more robust experiment dedicated to the specific influence of Israeli high schools' corrective grammatical curricula with respect to glottal stop realization and triconsonantal root preference (see Section 1.1) is needed to test this hypothesis. The results broken down into the two subject groups are shown below in Table 10. Note that 'Glottal' includes glottalization as an allophone of a full glottal stop (see Section 4.5).

Table 10: *Overall Results by Participant Background.*

Outcome	Participants 1 & 3 U.S. High School	Participants 2 & 4 Israeli High school
Novel Plural Nouns	60% Glottal	70% Glottal
Novel 3fs Verbs	20% Glottal	30% Glottal

5 Conclusion

This paper intended to address two research questions: (1) Does the glottal stop have phonemic status in the phonological inventories of Modern Hebrew speakers? (2) How do native Modern Hebrew speakers deduce the underlying forms of /ʔ/-final nouns and verbs? A production task was conducted with four native speakers of Modern Hebrew, who were asked to produce ten (10) novel /ʔ/-final 3fs verbs and ten (10) novel /ʔ/-final singular segholate nouns. The results provide evidence that while the glottal stop retains its phonemic status in Modern Hebrew, speakers prefer to realize underlying final glottal stops as an allophonic glottalization period in nouns, and to assume underlying final /j/ over underlying final glottal stops in verbs. Additionally, although speakers require a triconsonantal root for verbs, they exhibit only a weak preference for a third root consonant in nouns, indicating that this template may not be obligatory for nominals.

The scope of this study was not equipped to investigate the potential impact of Israeli institutions' robust, prescriptivist grammatical curricula and/or the influence of exposure to Biblical Hebrew and a religious educational background; however, results indicate that this is a subject worthy of further research in the future.

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7 Appendix: Participant Background Information

Table 11 below details participant background information with respect to age, gender, age of Hebrew acquisition, place of education, and self-reported religious exposure level. Any potentially relevant additional information is also included.

Table 11: Participant Background Information

Background	Participant 1	Participant 2	Participant 3	Participant 4
Age	22	31	21	20
Gender	Male	Male	Male	Male
Ages of Acquisition (FL = ‘First	FL: Hebrew; From birth	FL: Hebrew; From birth	FL: Hebrew; From birth	FL: Hebrew; Russian; From birth

Language')	SL: English; Started Age 6	SL: English; Starting 2nd grade	SL: English; Starting 2nd grade	SL: English; Starting 2nd grade
Education	Israel: 1st grade U.S: 2nd grade and above	Israel: All levels of education	Israel: Grades 1-6 U.S.: 7th grade and above	Israel: All levels of education
Religious Background	Strong	Weak	Strong	None
Additional Information	Frequently reads books in Hebrew.	Learned English in school and through English language media.	Doesn't read books in Hebrew; Grandmother is a Hebrew language instructor.	Learned English in school and through English language media.

About the Author

Madeleine Kostant-Greeley graduated from the University of California, Los Angeles (UCLA) in 2023 with B.A.'s in Applied Linguistics and Political Science. She is currently working in Madrid, Spain, and is planning to attend law school in Fall 2024. Her linguistic areas of interest include Phonology and Sociolinguistics.

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