

# Revisiting Tone Sandhi Domain in Xiamen Chinese

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## 1 Introduction

Current approaches to the syntax-prosody interface in the OT framework have proposed a number of constraints to force isomorphism between syntactic structures and prosodic structures. Among these, there are two major approaches, Match theory and Align/Wrap theory. Match theory requires the direct correspondence between phonological phrases  $\phi$  and syntactic XPs (Selkirk 2011, Elfner 2012, Myrberg 2013). Align, on the other hand, merely requires the alignment of the edges of syntactic XPs and phonological phrases (Truckenbrodt 1995, 1999, Selkirk, 1986). Wrap is an even looser requirement that forces XPs to be encapsulated in phonological phrases. What is common between Match theory and Align/Wrap is that they both admit that any mismatches between syntax and phonology phrasing should be driven by the prosodic well-formedness constraints like BINARITY, EQUAL SIZES, STRONG START, etc.

Both accounts operate on the same general syntax-prosody interface and care about the same prosody matching phenomena. One can ask a natural question: can one be replaced by the other? The motivation for this question comes from the minimal differences between the two theories. If one requires both the left and right edges of phonological phrases  $\phi$  to align with both the left/right edges of syntactic phrases, does that give the same predictions as Match? Also, Match theory has been equipped with richer prosodic subcategorizations such as Minor and Major Phrases and develops the corresponding MATCHMAX, MATCHMIN and MATCHNONMIN constraints to allow matching on different layers of  $\phi$ . This finer distinction within phonological phrases by itself empowers Match with more flexible empirical and conceptual coverages and less dependency on prosodic well-formedness constraints (Ishihara, 2014; Ito & Mester, 2009). However, this subcategorization has not yet been established in Align/Wrap.

In this paper, we use the tone sandhi domain in Xiamen Chinese as a case study to demonstrate that Match gives a much elegant explanation than Align/Wrap because it allows for subcategorization. MATCHNONMIN and MATCHMAX, when interacting with general MATCHSP, are enough to predict the tone sandhi domain in Xiamen Chinese. Align/Wrap, on the other hand, needs a prosodic well-formedness constraint such as BINARITY to dominate Align/Wrap. Altogether, we take this as a piece of evidence for the richer and fine-grained prosodic subcategorizations.

The comparison between Match and Align/Wrap is conducted in the SPOT, a collaborative research project in the linguistics department at the University of California, Santa Cruz, which aims to develop new tools for rigorously investigating the mapping from syntactic to prosodic structure (Syntax Prosody in Optimality Theory, <https://spot.sites.ucsc.edu/>). The major contribution of SPOT is that it allows for automatic candidate generation, thus considering all the possible prosodic parsing of each node in syntactic trees, including terminal lexical items and non-terminal syntactic phrases. The automatic evaluation of all the possible candidates is done in the OTworkplace, a crucial tool to evaluate candidates and conduct factorial typologies in Excel (Prince, Tesar, & Merchant, 2015). The structure of this paper is as follows: Section 2 presents the language data from Xiamen Chinese. Section 3 describes constraints and set-ups in OTworkplace and SPOT. Section 4 reports our major findings and Section 5 concludes.

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## 2 Xiamen Chinese

Xiamen is a coastline city in Fujian Province which is the main base for Min Dialect. It has a population of around 3.5 million among which 1.5 million are proficient speakers. The rest are speakers of other Chinese dialects like standard Mandarin or Hakka. Like most of the dialects in China, Xiamen has a limited inventory of syllable structure, namely, [initial [onglide [nucleus + coda]]] (Chen, 1987). The only permissible codas in Xiamen are nasals, glides, and voiceless stops. Like most Chinese dialects, Xiamen Chinese is also a tonal language that has seven citation tones as in (1). The tones are represented in Chao numeric letters where the highest number 5 is the highest pitch and 1 represents the lowest pitch (1960). Some examples of minimal pairs are shown in Table 1. Like other dialects in China, it has a distinction between checked syllables and free or smooth syllables. Checked syllables are the ones that end in stops whereas free syllables are ended with other consonants like nasals and glides. The distinction between free and checked syllables is important because they are subject to different tone sandhi rules. Whereas free syllables form a tone sandhi circle as in (2a), checked syllables have their own distinctive sandhi rules as in (2b). For instance, a free syllable with a 22 base tone will surface as a 21 tone. A checked syllable will surface as 21 if the base tone is 4 and as 4 if its base tone is 32 and it is ended in voiceless stop /p, t, k/.

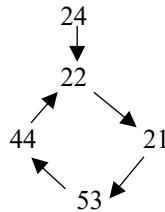
- (1) The citation tones (in Chao tone letters (1968))  
 a. 44 b. 24 c. 53 d. 21 e. 22 f. 32 g. 4.

po 44 褒 ‘praise’	si 44 诗 ‘poetry’
po 24 婆 ‘old woman’	si 24 时 ‘time’
po 53 宝 ‘precious’	si 53 死 ‘die’
po 21 报 ‘report’	si 21 四 ‘four’
po 22 暴 ‘violence’	si 22 寺 ‘temple’
po? 32 博 ‘extensive’	si? 32 薛 ‘Xue’ (a common Chinese family name)
po? 4 薄 ‘thin’	si? 4 蚀 ‘erosion’

Table 1. Minimal pairs of Xiamen citation tones

- (2) The mode of tone sandhi in Xiamen Chinese

- a. Free syllables:



- b. checked syllables:

- a) 4 → 21 (-p, -t, -k, -?)  
 b) 32 → 4 (-p, -t, -k)  
     53 (-?)

(Chen, 1987)

The basic tone sandhi rule in Xiamen Chinese is that base tones are preserved at the right edge of tone group (TG) and undergo sandhi elsewhere, which is formalized as in (3). The base tone is the conditioning environment for the tone sandhi within a tone group and the faithful surface of a base tone marks up the right edge of a tone group. In the following, we will follow the tradition using # to mark the right edge of a tone group.

- (3) Tone sandhi rules (TSR)

$T \rightarrow T' / \_\_\_ T$  within a tone group

(T=base tone; T'= sandhi tone)

(Chen 1987)

(4) *TG formation in Xiamen*

The domain of tone sandhi in Xiamen Chinese corresponds to phonological phrases  $\varphi$ .

There are some pieces of evidence suggesting that  $\varphi$  is the domain tone sandhi operates upon. One piece of evidence comes from the converging analysis in non-OT analysis that attribute TG to syntactic phrases XP. For instance, Chen (1992) argues that the right edge of every XP corresponds to the right edge of a TG except when XP is an adjunct c-commanding its lexical head. Lin (1994) argues that the maximal projection of a lexical head is the TG. A more recent proposal by Zhang (2020) also argues that the ridge edge of every XP is the one that matters for tone group formation in Xiamen Chinese. The consensus among the above approaches suggests that XP, or its prosodic correspondent  $\varphi$ , is the relevant domain for tone sandhi to take place in.

I follow Truckenbrodt (1999) in interpreting the domain of tone sandhi as  $\varphi$ , and assuming that no phonological recursion is involved in these structures. The reason for NONRECURSIVITY is for simplicity's sake. Since there is no diagnostics for the left edge of a TG, allowing a recursive  $\varphi$  creates unnecessary complexities. One complexity is that we have to define which  $\varphi$ , the maximal  $\varphi$  or the minimal  $\varphi$ , should correspond to a TG. However, the choice of NONRECURSIVITY is against the spirit of Match theory because Match usually allows for the recursive structures in the output form. But we will show in the later section that Match theory can handle such a simplification due to its large repertoires of different subcategorized Match constraints.

To summarize, in this section we discussed the general TGs in Xiamen Chinese and proposed that the right edge of TG correspond to the right edge of phonological phrases  $\varphi$ . In the following subsections, we will discuss several structures that demonstrate interesting syntax to prosody mappings.

**2.1 Adjunct vs. arguments** One remarkable characteristic about TG in Xiamen Chinese is that unlike arguments, adjuncts cannot form its own TG. Instead, it must adjoin with its head in TG. The difference between the two can be illustrated by an ambiguous sentence with their different meanings represented by (5) and (6). In (5), when *sesame-seed big* is interpreted as a relative clause that modifies the head noun *bun*, both lexical items form its own TG. This is demonstrated by the faithful surfacing of the underlying tone in *sesame-seed* and *big*. In (6), when *sesame-seed* is a modifier for the adjective *big*, they together form a single TG. This is shown by the surface of the sandhi tone in *seed*. The final prosodic outputs for (5) and (6) are given in (7).

(5) [mua-a]<sub>NP</sub> [tua]<sub>AP</sub> e sio-piã  
[Sesame-seed] # [big] # [COMP bun] #  
“buns on which the sesame seeds are big”

(6) [[mua-a]<sub>NP</sub> [tua]<sub>AP</sub>]<sub>AP</sub> e sio-piã  
[Sesame-seed big] # [COMP bun] #  
“buns as big as sesame-seed”

(Chen, 1978)

(7) Prosodic outputs of (6) and (7)  
{(sesame-seed)<sub>NP</sub> (big)<sub>AP</sub>}<sub>TP</sub> → {<sub>i</sub> ( $\varphi$  sesame-seed) ( $\varphi$  big)}  
((sesame-seed)<sub>NP</sub> (big)<sub>AP</sub>)<sub>AP</sub> → ( $\varphi$  sesame-seed big)

**2.2 Sentential adjuncts vs. VP adjuncts** Like the adjunct-argument distinctions, VP-adjuncts cannot form its own TG whereas sentential-adjuncts can. An example of such cases is in (8) and (9). The key difference in term of prosodic structures between the two is that *probably*, as an adjunct to the entire sentence, forms its own prosodic phrase whereas *already* does not. When deriving the above generalizations about the difference between sentential-adjuncts and VP-adjuncts, we ignore the pronoun *he* because it has been proposed that pronouns cliticize to the right head and do not form a prosodic word on their own (Chen, 1987). This invisibility of lexical items like pronoun can also be extended to functional items like inflectional lexicals, aspect and tense markers, etc. Constraints that regulate syntactic and prosodic categories only apply to lexical syntactic elements and their projections, but not to functional elements and their projections. This lexical category restriction, formulated in (11), has been proposed in different versions and well-accepted in previous works (Selkirk 1995; Selkirk & Shen 1990).

(8) yi yi-king tsu a  
 [He already go ASP] #  
 ‘He has already gone.’

(9) yi tai-k'ai tsu a  
 [He probably] # [go ASP]#  
 ‘He probably has gone.’

(10) Prosodic outputs of (9) and (10)  
 [[he-already]<sub>AdvP</sub>[go]<sub>VP</sub>]<sub>VP</sub> → {<sub>i</sub> (φ already go)}  
 [[he-probably]<sub>AdvP</sub> [[go]<sub>VP</sub>]<sub>T'</sub> → {<sub>i</sub> (φ probably) (φ go)}

(11) Lexical Category Condition  
 Constraints relating syntactic and prosodic categories apply to lexical syntactic elements and their projections, but not to functional elements and their projections.

**2.3 Double-object constructions** Another construction that demonstrates the adjunct-argument differences is the double-object construction of ditransitive verbs. Just like regular argument structures, both direct and indirect objects can form its own TG in Xiamen Chinese. An example of such construction is in (12) and (13). We see a TG boundary for each of the objects for the verb *give*.

Based on the distribution of tone sandhi, we infer that both objects correspond to φ. Thus, *to schoolmate* is a phonological phrase. Since we assumed that NONRECURSIVITY, we made a choice that the highest φ that corresponds to *that book give to schoolmate* and the lowest φ for *to schoolmate* lost their status. Thus, the final output prosodic structure for (19) is {<sub>i</sub> (φ *that book*) (φ *give to schoolmate*)} as in (15). There are two things to note here. First of all, it is not the only available analysis for such a structure. An alternative analysis would be {<sub>i</sub> (φ *that book*) *give* (φ *to schoolmate*)} where the lowest φ *to schoolmate* retain their φ status and the intermediate φ is lost. This analysis is also compatible with the tone sandhi pattern in Xiamen Chinese because *tang-oq* “schoolmate” marks the right edge of φ and both (φ *give to schoolmate*) and *give* (φ *to schoolmate*) are compatible with this tone sandhi change. We made a theoretic choice that the former is the final prosodic output for [*go* [*to schoolmate*]<sub>PP</sub>]<sub>VP</sub>. There are two reasons for such a choice. First, the latter analysis violates EQUALSISTERS. Having a prosodic word *give* as a sister to a phonological phrase (φ *to schoolmate*) violates EQUALSISTERS. But independent evidence is needed to support that EQUALSISTERS is relevant for Xiamen Chinese. It also violates EXHAUSTIVITY because <sub>i</sub> directly dominates a prosodic word *give*. Again, independent evidence is needed to show that both EQUALSISTERS and EXHAUSTIVITY are relevant. This theoretical choice is inferred from the tone sandhi pattern in Xiamen Chinese and from the general well-formedness requirements for prosodic structures.

(12) yi tsiong hit pun ts'eq sang hoo tang-oq  
 [he obj-marker that CI book] # [give to schoolmate] #  
 ‘He gave that book to his schoolmate.’

(13) yi kap tang-oq kai-siao tsit e lu-ping-yu  
 [He to schoolmate] # [introduce one CI girlfriend] #  
 ‘He introduced a girlfriend to his schoolmate.’

(14) Prosodic structure output of (19) and (20)  
 [[he]<sub>NP</sub>[[that-book]<sub>DP</sub> [go [to schoolmate]<sub>PP</sub>]<sub>VP</sub>]<sub>VP</sub>]<sub>TP</sub> → {<sub>i</sub> (φ *that book*) (φ *give to schoolmate*)}  
 [[he]<sub>NP</sub>[[to schoolmate]<sub>PP</sub> [introduce[a girlfriend]<sub>DP</sub>]<sub>V'</sub>]<sub>VP</sub>]<sub>TP</sub> → {<sub>i</sub>(φ *to schoolmate*)(φ *introduce a girlfriend*)}

**2.4 Topic movement** Another interesting construction that is often discussed in Xiamen Chinese is sentences that have undergo topic movement as in (15) and (16). The basic pattern is that when a NP is topicalized by leftward movement, it forms its own. Whether the remaining QP forms its own TG depends on its grammatical structures with the rest of the sentence. If it is part of the VP, then it does not form a TG. If it is part of the VP that serves the subject of the entire sentence, it the remaining QP also forms an independent TG.

- (15) liok-yah-p'ih tso tsit ts'ut lai k'uah  
 [video-movie ]# [rent one CI to watch]#  
 'Rent one video-movie to watch'
- (16) liok-yah-p'ih tso tsit ts'ut# tsin kui  
 [video-movie]# [rent one CI]# [very expensive]#  
 'It is very expensive to rent one video-movie.'

We observe that when the argument NP *liok-yah-p'ih* "video-game" is topicalized, it always forms its own TG. But what really make (15) and (16) different is that the silent copy of the movement in (15) remains inside a prosodic word not in the domain of a prosodic phrase as in (16). This analysis relies on the assumption that that silent copy is not involved in the prosodic mapping. We take it as a legitimate assumption that the phrase movement takes place at Surface Form. Thus, the silent copy remains invisible thus does not form its own prosodic category. The final prosodic output is given in (17).

- (17) Prosodic output of (15) and (16)
- [[video-game]<sub>NP</sub> [[[rent one]<sub>V</sub> [to watch]<sub>PP</sub>]<sub>VP</sub>]<sub>TP</sub>]<sub>CP</sub> → {<sub>t</sub> (ϕ video-game) (ϕ rent watch)}
- [[video-game]<sub>NP</sub> [[[rent one]<sub>VP</sub> [very expensive]<sub>AP</sub>]<sub>TP</sub>]<sub>CP</sub> → {<sub>t</sub> (ϕ video-game) (ϕ rent) (ϕ expensive)}

**2.5 Data Summary** Based on what we have discussed so far, the overall picture for Xiamen Chinese is that non-minimal XPs are always matched, but minimal XPs are not. For instance, in adjunction structures, the higher XP that incorporates the adjunct is matched to a ϕ and the lower XP for the adjunct is reduced to a prosodic word. Again, the interpretation of adjunction structures as non-minimal depends on the analytical choice. This choice suggests that at least the higher segment of the adjunction structures is visible to the syntax-prosody mapping. The generalizations for each the above constructions are summarized in Table 2.

Syntactic structures	Examples	Output prosodic structures
Argument vs. Adjunct	[S [ <sub>NP</sub> sesame-seed] [ <sub>AP</sub> big]]	{ <sub>t</sub> (ϕ sesame-seed) (ϕ big)}
	[S [ <sub>AP</sub> [ <sub>NP</sub> sesame-seed] [ <sub>AP</sub> big]]]	(ϕ sesame-seed big)
VP adjunct vs. Sentential adjunct	[S [ <sub>VP</sub> [ <sub>AVP</sub> already] [ <sub>VP</sub> go]]]	(ϕ already go)
	[S [probably] <sub>AVP</sub> [go] VP]	{ <sub>t</sub> (ϕ probably) (ϕ go)}
Double objects	[VP [ <sub>NP</sub> that book] [ <sub>VP</sub> give [ <sub>NP</sub> schoolmate]]]	(ϕ that book) (ϕ give to schoolmate)
	[VP [ <sub>NP</sub> schoolmate] [introduce [ <sub>NP</sub> a girlfriend]]]	{ <sub>t</sub> (ϕ schoolmate) (ϕ introduce a girlfriend)}
Topic movement	[S [ <sub>VP</sub> [ <sub>NP</sub> video-game] [ <sub>VP</sub> rent [ <sub>VP</sub> watch]]]]]	{ <sub>t</sub> (ϕ video-game) (ϕ rent watch)}
	[S [ <sub>NP</sub> video-game] [VP [ <sub>VP</sub> rent] [ <sub>AP</sub> expensive]]]	{ <sub>t</sub> (ϕ video-game) (ϕ rent) (ϕ expensive)}

Table 2. Data summary of Xiamen Chinese TG

Abstracting away from all the detailed constructions, the formal characterization of the small phrase structure grammar of Xiamen tone sandhi is in (18). (18a) summarizes the tone sandhi domain in the adjunct structures in *sesame-seed big* and the VP adjuncts as in *already go* and states that adjuncts cannot form their own tone domain. (18b) schematizes the dative structures and topicalized structures. When in dative structures, both arguments form TGs and the lexical head cannot. In topicalized structures, the lexical head does not constituent a TG either. (18c) schematizes the argument structure in *sesame-seed big* and in sentential adjunct structures *probably go*, suggesting that all phrases immediately dominated by a sentence should form their own TGs.

- (18) Tone sandhi domain rules in Xiamen Chinese

- a.  $XP \rightarrow [YP \ XP] \#$       where YP is adjunct to the host structure XP.
- b.  $XP \rightarrow [YP \# [X_0 \ ZP]_{XP} \#]$       where  $X_0$  is the lexical head and YP/ZP are its arguments.
- c.  $S \rightarrow [XP \# YP \# (ZP \#)]$       where XP and YP are daughters of a sentence.

### 3 SPOT Setup

Now that we have the full repertoire of prosodic output forms in Xiamen Chinese, we then derive these forms using Align/Wrap and Match in OT system respectively. The OT analysis is done in SPOT and OTworkplace. SPOT consists of two separate mechanisms, GEN and CONS. GEN generates input syntactic trees and have output parameters to constrain the set of output forms. Input syntactic trees for each structure were built using SPOT's algorithm. Output parameters also include relevant settings that constrain the possible outputs of GEN. For instance, NONRECURSIVITY and EXHAUSITIVITY is built in the GEN output parameter. Practitioners can decide which parameters are relevant for the language data one studies. The relevant parameter we think relevant for Xiamen Chinese is NONRECURSIVITY because we assume that the higher XP corresponds to phonological phrases  $\varphi$  while reducing non-maximal projections to a prosodic word  $\omega$ . We have to acknowledge that it is not a usual choice for Match theory because Match usually allows for recursion in prosodic structures to match the recursion in syntactic structures. But the current system can still be considered to be a subset of a larger system where the constraints NONRECURSIVITY and EXHAUSITIVITY are undominated, thus are part of the constraint set, rather than being constraints on GEN. In prosodic categories specification, we chose  $\iota$  as the root node for all prosodic trees. The motivation for  $\iota$  to be the root comes from the fact that some phonological phrases  $\varphi$  are immediately dominated by  $\iota$ , thus relevant for our analysis of TG in Xiamen Chinese. We also assume Strict Layering is also enforced in our current system and strict layering is a standard assumption in syntax-prosody matching enterprise. The output specifications for GEN are in (19). The output form of SPOT is a violation tableau that evaluates all the possible candidates by the constraints one chooses. OTWorkplace provides a useful tool for constraint rankings and factorial typology running (Prince, Tesar, & Merchant 2015). After the violation tableau has been outputted, we feed it into OTworkplace to conduct a factorial typology which predicts all the possible languages one can get based on different rankings of constraints. This way, an automatic factorial typology and constraint rankings on all the possible candidates can be obtained, thus providing a comprehensive and rigorous OT investigations of the syntax-prosody mapping.

(19) GEN Output parameters:

- a. *NONRECURSIVITY*:  
No prosodic tree will contain a node of category K that dominates another node of category K.
- b. *Root prosodic tree in  $\iota$* :  
The category of the root node for all the prosodic trees created by GEN is  $\iota$ .
- c. *Strict Layering*:  
A constituent of category-level n in the prosodic hierarchy immediately dominates only a sequence of constituents at category-level n-1 in the hierarchy (Selkirk, 2011).

### 4 Match vs. Align/Wrap

Since the purpose of this paper is to compare the predictive powers of Match theory and Align/Wrap theory, we run two SPOT analysis separately: one analysis only using Match theory and one only Align/Wrap theory. To provide a preview of our results, we find that Match theory alone can explain the TG in Xiamen Chinese without the need of other prosodic wellformedness constraints whereas Align/Wrap will give a ranking paradox. However, an introduction of BINARITY that outranks Align/Wrap will give us the correct output forms. We show that Xiamen Chinese TG is sensitive to the different subcategories of phonological phrases  $\varphi$ . The theoretical merit of Match theory comes from its rich subcategorization apparatus. But this subcategorization has not been proposed in Align/Wrap yet and it needs prosodic well-formedness constraints to generate the correct optimal outputs.

**4.1 Match** The definitions of the relevant Match constraints, MATCHSP(xp), MATCHNONMINSYNTAX(xp), and MATCHMAXSP-LEXICAL(xp) are given in (20). The choice of

constraints is determined by the following factors. First, we need MATCHNONMIN because the TG in Xiamen Tone sandhi show that non-minimal XPs correspond to TGs and thus to a  $\varphi$ . Second, we might also assume that MATCHMAXSP would be relevant for TG formation, so we include it for comparisons. Third, the reason why we did not include any Match constraints from prosody to syntax is that none of them were violated among our candidates, thus irrelevant for our purposes. Based on LLC, we decided that lexical phrases are what matters for tone group formations, thus this lexical requirement is built in the MATCHMAXSP-LEXICAL(xp) constraint. After we run the factorial typology in OTworkplace using the above three constraints, we found that it generates three languages and Language 2 is Xiamen Chinese. The full factorial typology is in Table 3.

(20) Match Constraints definitions:

- a. MATCHSP (xp): Assign one violation for every XP in the syntactic tree such that there is no node of the corresponding prosodic category  $\varphi$  in the prosodic tree that dominates the same set of terminals (Selkirk 2011).
- b. MATCHNONMINSYNTAX (xp): Assign one violation for every non-minimal XP in the syntactic tree for which there is no  $\varphi$  in the prosodic tree that dominates all and only the same terminals. A XP is non-minimal iff it dominates at least one XP (Ito & Mester 2009).
- c. MATCHMAXSP-LEXICAL (xp): Assign one violation for every maximal XP in the syntactic tree such that there is no maximal  $\varphi$  that dominates all and only the same terminal nodes in the prosodic tree. A node XP is maximal iff it is not dominated by any other XP (Ishihara 2014).

Input	L1	L2	L3
{{[already] [go]}}	{{(already go)}}	{{(already go)}}	{{(already) (go)}}
{{[probably][go]}}	{{(probably)(go)}}	{{(probably)(go)}}	{{(probably)(go)}}
{{[[book][gave [schoolmate]]]}	{{(book gave schoolmate)}}	{{(book) (gave schoolmate)}}	{{(book) (gave schoolmate)}}
{{[[schoolmate][introduce [girlfriend]]]}	{{(schoolmate introduce girlfriend)}}	{{(schoolmate) (introduce girlfriend)}}	{{(schoolmate) (introduce girlfriend)}}
{{[[rent [videogame] [watch]]]}	{{(rent videogame watch)}}	{{(rent videogame) (watch)}}	{{(rent videogame) (watch)}}
{{[videogame] [rent [watch]]}}	{{(videogame) (rent watch)}}	{{(videogame) (rent watch)}}	{{(videogame) (rent watch)}}
{{[sesame] [big]}}	{{(sesame)(big)}}	{{(sesame)(big)}}	{{(sesame)(big)}}
{{[[sesame] [big]]}}	{{(sesame big)}}	{{(sesame big)}}	{{(sesame big)}}

Table 3. Factorial typology of Match constraints

The crucial relevant sample winner-loser pairs are given in Table 3. For  $\{[already][go]\}$ , the winner is the one that both *already* and *go* lose its phonological phrase status and downgraded to a prosodic word. It violates MATCHSP (xp) because *already* and *go* has no corresponding phonological phrases in prosodic structures. However, it satisfies both MATCHNONMINSYNTAX(xp) and MATCHMAXSP-LEXICAL(xp) because both the non-minimal and the max XP, namely, the maximal XP that dominates both *already* and *go* corresponds to a  $\varphi$ . So, either one should dominate MATCHSP (xp). For  $\{[[book] [gave [schoolmate]]]\}$ , we want the winner to be the one that *book* and *gave schoolmate* each has its corresponding  $\varphi$ . But it violates MATCHMAXSP-LEXICAL(xp) because the maximal XP that incorporates *book* and *gave to schoolmate* is not mapped to a  $\varphi$ . But the optimal output has one less violation of MATCHSP (xp) than the loser  $\{(book\ gave\ schoolmate)\}$ , which violate MATCHSP (xp) twice. Therefore, MATCHSP (xp) should dominate MATCHMAXSP-LEXICAL(xp). Using implicational relations, we now conclude the constraint rankings relations is that MATCHNONMINSYNTAX (xp) dominates MATCHSP (xp) that again dominates MATCHMAXSP-LEXICAL(xp).

Language 1 is the one that preserves the highest  $\varphi$  status, thus all non-high  $\varphi$ s are downgraded to prosodic words. This retention of the highest phonological phrase is achieved by the dominance of MATCHMAXSP-LEXICAL(xp) over MATCHSP (xp). Thus, it gives the same predications as Xiamen Chinese in two-word input but wrong predictions for three-word input. For instance, for *book give to schoolmate*, it predicts that

the string corresponds to one  $\phi$  altogether. This language has a very loose requirement for syntax-prosody matching. Language 3, on the other hand, has MATCHSP (xp) dominate both MATCHMAXSP-LEXICAL(xp) and MATCHNONMINSYNTAX (xp). In this language, both adjuncts and arguments correspond to  $\phi$ . It has a stricter requirement for syntax-prosody matching than the other two languages. Among the three languages, L2 is the intermediate one in terms of rigidity between syntax and prosody. It allows for some degree of syntax-prosody unfaithfulness but also preserves the faithfulness between the two to some extent.

Input	Winner	Loser	MATCHNONMINSYNTAX(xp)	MATCH SP (xp)	MATCHMAX SP-LEXICAL(xp)
{{[already] [go]}}	{{(already go)}}	{{(already) (go)}}	<b>W</b>	L	<b>W</b>
{{[sesame] [big]}}	{{(sesame big)}}	{{(sesame) (big)}}	<b>W</b>	L	<b>W</b>
{{[book] [gave] [schoolmate]}}	{{(book) (gave schoolmate)}}	{{(book gave schoolmate)}}		<b>W</b>	L
{{[schoolmate] [introduce] [girlfriend]}}	{{(schoolmate) (introduce girlfriend)}}	{{(schoolmate introduce girlfriend)}}		<b>W</b>	L
{{[rent] [videogame] [watch]}}	{{(rent videogame) (watch)}}	{{(rent videogame watch)}}		<b>W</b>	L

Table 4. Winner-loser pairs in Xiamen Chinese

**4.2 Wrap/Align** When we run an OT analysis in OTworkplace using only WRAP-XP and ALIGNRIGHT-XP/ALIGNLEFT-XP, it generates two languages, L1 and L2. The definition of each constraint is in (21) and the factorial typology is in Table 5. Among the two languages, neither gives us Xiamen Chinese. For instance, WRAP-XP dominates ALIGNRIGHT-XP/ALIGNLEFT-XP in L1. It requires all syntax phrases to be wrapped in a phonological phrase  $\phi$ . It gives the correct predictions for two-word input but not for three-word input. Because some of the three-words input correspond to one XP, WRAP-XP demands a  $\phi$  to encapsulate it. Also, since NONRECURSIVITY remain undominated, the optimal output in L1 for a three-word input is that there is only one  $\phi$  to wrap all XPs. L2 requires ALIGNRIGHT-XP to dominate WRAP-XP. It gives the same predictions for three-word inputs as Xiamen Chinese, but not for two-word inputs. For instance, the optimal form for {{[sesame] [big]}} is the faithful {{(sesame) (big)}} because it requires the right edge of the XP to align with the right edge of  $\phi$ . The correct optimal form {{(sesame big)}} is penalized by ALIGNRIGHT-XP because there is *sesame* is not aligned with any right edge of  $\phi$ .

The key winner-loser pairs for Align/Wrap are given in Table 6. Our winner {{(already go)}} for the syntactic input {{[already] [go]}} violates ALIGNRIGHT-XP once because *already* in the input syntactic tree does not align to the right edge of a phonological phrase  $\phi$  due to the presence of *go*. But it satisfies WRAP-XP because both *already* and *go* are enclosed within a bigger  $\phi$ . So, WRAP-XP should dominate ALIGNRIGHT-XP to give us the correct optimal output form for {{[already] [go]}}. However, for {{[book] [gave] [schoolmate]}}}, the optimal output {{(book) (gave schoolmate)}} violates WRAP-XP but satisfies ALIGNRIGHT-XP. It violates WRAP-XP because the highest XP that contains both *book* and *gave schoolmate* is not encapsulated in any  $\phi$ . It satisfies ALIGNRIGHT-XP because both *book* and *gave schoolmate* each aligned to the right edge of a  $\phi$  that they each correspond to. So, for the correct output form {{(book) (gave schoolmate)}} to win, we need WRAP-XP and ALIGNRIGHT-XP to dominate WRAP-XP. We hereby have a ranking conflict between WRAP-XP and ALIGNRIGHT-XP.

## (21) WRAP/ALIGN Constraints definitions:

- a. WRAP-XP: Assign one violation for every XP in the syntactic tree that does not have a corresponding  $\phi$  in the prosodic tree, where  $\phi$  contains all the terminals dominated by XP (Truckenbrodt 1995, 1999).
- b. ALIGNRIGHT-XP: Assign one violation for every XP in the syntactic tree whose right edge is not aligned with the right edge of  $\phi$  in the prosodic tree (Selkirk 1986, 1996; McCarthy & Prince 1993; Truckenbrodt 1995, 1999).

Input	L1	L2
{{[already] [go]}}	{{(already go)}}	{{(already go)}}
{{[probably][go]}}	{{(probably)(go)}}	{{(probably)(go)}}
{{[book][gave [schoolmate]]}}	{{(book gave schoolmate)}}	{{(book) (gave schoolmate)}}
{{[schoolmate][introduce [girlfriend]]}}	{{(schoolmate introduce girlfriend)}}	{{(schoolmate) (introduce girlfriend)}}
{{[rent [videogame]] [watch]}}	{{(rent videogame watch)}}	{{(rent videogame) (watch)}}
{{[videogame] [rent [watch]]}}	{{(videogame) (rent watch)}}	{{(videogame) (rent watch)}}
{{[sesame] [big]}}	{{(sesame)(big)}}	{{(sesame)(big)}}
{{[sesame] [big]}}	{{(sesame big)}}	{{(sesame big)}}

Table 5. Factorial typology of Wrap/Align constraints

Input	Winner	Loser	WRAP(xp)	ALIGNRIGHT(xp)	ALIGNLEFT (xp)
{{[already] [go]}}	{{(already go)}}	{{(already) (go)}}	W	L	L
{{[sesame] [big]}}	{{(sesame big)}}	{{(sesame) (big)}}	W	L	L
{{[book] [gave [schoolmate]]}}	{{(book) (gave schoolmate)}}	{{(book gave schoolmate)}}	L	W	L
{{[schoolmate] [introduce [girlfriend]]}}	{{(schoolmate) (introduce girlfriend)}}	{{(schoolmate introduce girlfriend)}}	L	W	L
{{[rent [videogame] [watch]]}}	{{(rent videogame) (watch)}}	{{(rent videogame watch)}}	L	W	L

Table 6. Winner-Loser pairs using Align/Wrap theory

Since we derived a conflicting ranking between WRAP-XP and ALIGNRIGHT-XP, a classical solution for this conflict is to introduce another constraint that dominates both. Here we introduce BINMAX that demands that any  $\phi$  should not have more than two children. The definition of this constraint is in (23). For our two-word input, *{{[already] [go]}}* and *{{[sesame] [big]}}*, neither violates BINMAX because neither has a  $\phi$  that has more than three children. BINMAX is unable to decide between the winner and loser candidates. However, for three-word input *{{[book] [gave [schoolmate]]}}*, it penalizes the loser *{{(book gave schoolmate)}}* because the one and only one  $\phi$  in the prosodic output contains three prosodic words. Though WRAP-XP favors the loser for the three-word input, it is dominated by a higher constraint BINMAX, thus giving us the correct output form. Here we have our constraint rankings ready: BINMAX dominates WRAP-XP that further dominates ALIGNRIGHT-XP. Thus, the conflicting rankings between WRAP-XP and ALIGNRIGHT-XP is resolved by the introduction of a higher prosodic well-formedness constraint BINMAX.

This is not the only viable solution to this conflicting ranking problem. Another option would be ALIGNRIGHT-XP[NONMIN]. But as we said earlier, the subcategorization for  $\varphi$  is not yet established as a well-accepted category in Align family. This is the point we will make in the discussion and conclusion section.

(23) BINMAX (branches)

Assign one violation for  $\varphi$  in the prosodic tree that has more than two children (Elfner, 2012).

Input	Winner	Loser	BINMAX (branches)	WRAP -XP	ALIGNRIGHT- XP	ALIGNLEFT- (xp)
{[[already] [go]]}	{(already go)}	{(already (go)}		<b>W</b>	<b>L</b>	<b>L</b>
{[[sesame] [big]]}	{(sesame big)}	{(sesame (big)}		<b>W</b>	<b>L</b>	<b>L</b>
{{[[book] [gave [schoolmate]]]}	{{(book) (gave schoolmate)}	{{(book gave schoolmate)}	<b>W</b>	<b>L</b>	<b>W</b>	<b>L</b>
{{[[schoolmate] [introduce [girlfriend]]]}	{{(schoolmate) (introduce girlfriend)}	{{(schoolmate introduce girlfriend)}	<b>W</b>	<b>L</b>	<b>W</b>	<b>L</b>
{{[[rent [videogame] [watch]]]}	{{(rent videogame) (watch)}	{{(rent videogame watch)}	<b>W</b>	<b>L</b>	<b>W</b>	<b>L</b>

Table 7. Winner-Loser pairs in Wrap/Align theory with BINMAX.

## 5 Discussion and conclusion

Summarizing what we have analyzed for the TG in Xiamen Chinese, we found that adjunction structures behave differently with respect to arguments because adjunctions cannot form their own independent TGs whereas arguments can. Adjuncts must adjoin with its left or right head to form a TG. We analyzed the TG in different constructions, including VP-adjuncts vs. sentential-adjuncts, dative constructions and topicalized sentences using Match constraints and Wrap/Align theories in SPOT and OTworkplace. We found that Match constraints alone can derive the correct optimal output for the above constructions because it has a richer subcategorization for  $\varphi$ , whereas Wrap/Align must combine with a prosodic well-formedness constraint BINMAX in order to give us the right output.

But we have to make a cautious point here. The premise for both Match and Wrap/Align to work is that NONRECURSIVITY and Strict Layering remain undominated. This is a theoretical choice rather than an independently motivated constraint. Also, when analyzing dative structures and deriving their output prosodic structures, we have already assumed that another prosodic markedness constraint EQUALSISTERS are involved. Again, this is an analytic choice, rather than independently motivated. The reason why Xiamen Chinese allows for such an analytic flexibility is that only the right edge of TGs is marked up with some prosodic phenomenon. There is nothing to detect the left edge of a TG. However, if we assume that TG is  $\varphi$ , we could use other parameters like interval time between  $\varphi$  to pinpoint its left edge. But before any empirical data to show the left edge is available, we have to make somewhat motivated analytic choice.

If we accept the abovementioned premise and analysis, do the findings suggest that Match theories is more explanatorily adequate than Wrap/Align given that Match alone, without relying on other motivated constraints, is good enough? Well, it is far from clear whether the lack of reliance on other constraints is a merit to celebrate. But it appears that Match allows more flexibility between syntactic structures and prosodic structures, though Match requires that prosody should match syntax as close as possible. This flexibility of mismatches comes from the big families of Match constraints, which demands matches on different prosodic levels. Like the ones we used in Xiamen Chinese, it not only requires the maximal XP to have a corresponding  $\varphi$  in the prosodic tree, just as MATCHMAXSP (xp). Match also have MATCHNONMINSYNTAX (xp) that

demands the non-minimal XP to have a  $\phi$ . The tensions of Match between syntax phrasing and phonological phrasing on different levels gives us the freedom to derive as many output forms as possible.

Compared with Match, Align/Wrap seems to be restricted on the levels of prosody it operates upon. The layered differences like, the minimal  $\phi$ , the non-minimal  $\phi$ , the max  $\phi$ , for instance, cannot be distinguished in Align/Wrap. Wrap, for example, only requires a XP to be enclosed by a  $\phi$ , regardless of its layered status. Either a XP is wrapped up within a minimal  $\phi$  or a max  $\phi$  does seem to matter. So, Wrap is very tolerant with different output forms and very few outputs will be penalized by Wrap. Only the ones that is not encapsulated by any  $\phi$  is ruled out as ungrammatical. But does it mean that Wrap is not a good constraint at all? It is hardly so. Allowing more output forms is not necessarily a bad feature for a constraint. The lack of subcategorization of  $\phi$  in Align Theory is because it was normally used in the context of Strict layering, thus prohibiting the recursion of  $\phi$ . But SPOT has options for subcategorization. But what types of optimal output it will give us remains future research.

In general, the OT analysis is more elegant and simpler than other non-OT analysis of Xiamen Chinese TG. Several syntactic accounts using c-commanding/m-commanding or even lexical government have been proposed to account for this old question of tone group formation in Xiamen Chinese (Lin, 1994; Zhang, 2019; Chen, 1987, 1992). But they all explain the adjunct-argument distinction using an else-where condition. For instance, Zhang proposes that every right edge of every XP is marked with #, except where XP is an adjunct m-commanding either its head or the head of XP on the right except Infl (2020). Non-OT analysis not only refers to the syntactic category XP, but also refers to syntactic relations like c-commanding or lexical government. In comparison, OT analysis only needs Match or Align/Wrap to ensure the correspondence between syntactic phrases and phonological phrases. All other mismatches are driven by prosodic well-formedness constraints. OT is a simpler system when compared with non-OT analysis.

The final point goes back to the question we proposed in the very beginning: can Match be reduced to Align/Wrap, or vice versa? Since both constraints can explain the Xiamen Chinese well, we have a weak argument favoring Match because Match alone can explain the TG in Xiamen Chinese because of its admittance of  $\phi$  subcategorization whereas Align/Wrap needs BINMAX. But whether no need of BINMAX is a good merit for a theory or not is still unclear. Also, there are cases showing that both theories are necessary for at least some syntax-prosody phenomena. Unless we have more solid evidence that converge on the explanatory adequacy of one theory versus the other, it is far too early for us to draw the bold conclusion that Match should replace Align/Wrap or the other way around, Align/Wrap should replace Match. But we can firmly draw another conclusion that subcategorization is much needed for different layers of prosodic structures, especially for phonological phrases  $\phi$ .

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