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A Literature Review on Centering Theory

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Abstract
Centering, a model of the conversants' center of attention in discourse, centers around the relationship between attentional state, inferential complexity and the form of referring expression. Concerned with the local coherence and semantic entity salience, Centering Theory is framed by two strands of early work: (i) research by Joshi, Kuhn and Weinstein (Joshi and Kuhn, 1979; Joshi, Weinstein, 1981); and (ii) research by Grosz and Sidner (Grosz, 1977; Sidner, 1979; Grosz, Sidner, 1986). A synthesis of the two trains of thoughts helps to make up a theoretical background for Centering Theory and a motivation for the future work, such as empirical studies and application studies. In the present article, in order to help the reader to understand the epochal significance of various fruits of recent couple of decades, an attempt to undertake a systematic review of Centering Theory will be made.

Key words: Centering theory; Discourse coherence; Parametric studies; *Center* transition

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INTRODUCTION

Centering, with its focus mainly on the relationship between discourse coherence, inference load, and the choice of referring expression (Grosz, Joshi, and Weinstein, 1986; 1995), is a theory of discourse coherence and salience (Poesio, Stevenson, Di Eugenio, Hitzeman, 2004), which are measured by tracking the attentional state of the speaker within a local discourse.

The division of a discourse (*D* for short) provides the basic rationale for Centering Theory. In Grosz et al.'s (Grosz, Joshi, and Weinstein, 1983) shrewd cognizance, a discourse comprises a host of utterances that can make up a discourse segment (*DS* for short). In brief, DS in centering model, as a subconstituent of the discourse (*D*), appears to be typically larger than a single sentence, but smaller than a complete discourse.

As well as being essential, a general picture of three layers within the discourse is depicted as follows: (i) a linguistic structure; (ii) an intentional structure; and (iii) an attentional state/ focusing structure. Notice that where the discourse proceeds, these three components also evolve (Grosz and Sidner, 1986). Based upon such layers, the typology of the "discourse coherence" ensues: (i) global coherence and (ii) local coherence (Grosz, Joshi, and Weinstein, 1983), being the first contention of centering model. Put another way, each discourse segment (*DS*) is posited to exhibit two levels of coherence. The former level is computed across the discourse segments, and is tantamount to the intersegmental coherence of a discourse, whereas the latter always involves the intrasegmental coherence that is computed at the level of a discourse segment.

The second contention of centering model is the focus of attention within a discourse. By Grosz, Joshi and Weinstein's (1995) scrupulous deliberations, centering is rated as a model of the local-level component of attentional state, and each utterance (U_n) is associated with a list of Forward-looking centers, *Cf* (U_n, *D*), that consist of two special members: (i) Backward-looking center, *Cb* (U_n, *D*); and (ii) Preferred center, *Cp* (U_n, *D*). And according to discourse salience, the ranking in *Cf* set, on one hand, helps to characterize one of the *Cf*s as the

Cb (U_{n+1}, *D*) and *Cp* (U_n, *D*), and, on the other hand, is instrumental to predict and interpret the updates of local focus in subsequent utterances.

In addition, a series of centering constraints and rules are provided. Due to the requirement of least processing (Grosz, Joshi, Weinstein, 1995), all of them can pull together to make a set of testable predictions about the interpretation that hearer prefers to.

In this article, for one thing, the first part will strain to conduct a relatively comprehensive literature review on aforesaid central statements. For another thing, pages are going to be devoted to combing the fertile body of contributions with regard to Centering Theory over the last decades.

1. GENERAL DESCRIPTION: FORMULATION

The centering approach of discourse structure, developed from two strands of previous researches, is a computational account of the local coherence of a discourse. In terms of this model, the local coherence can be assessed by virtue of the shifts of centered entities in adjacent utterances. At the same time, this model relates the interlocutors' focus of attention, choice of referring expression and perceived coherence of utterances within a discourse segment (*DS*) (Grosz, Joshi, Weinstein, 1986; 1995). In order to bring light on such relation, Centering Theory, with the focus mainly on discourse coherence and discourse salience, provides an overall framework for the discourse structure.

The fundamental assumption of centering model as far as the focus of attention within a discourse is concerned is that the basic structure of an utterance in discourse often singles out an entity to be called "center", which an utterance most centrally concerns (Joshi, Kuhn, 1979). This centered entity is further developed by two lines of research work. To be specific, two discourse models, that is, (i) discourse focusing model and (ii) discourse centering model, are put forth by the two trains of thoughts.

The former headed by Grosz et al. (Grosz, 1977; Sidner, 1979; Sidner, 1981; Sidner, 1983; Grosz, Joshi, Weinstein, 1983) centers around the focus of attention within a discourse. Enlightened by two levels of "discourse coherence", Grosz (1977) keenly proposes two levels of 'focusing' in discourse: (i) global focusing and (ii) immediate focusing. Later, the two cardinal types are further developed into (i) immediate discourse focus, (ii) actor focus, and (iii) a set of potential foci in Sidner's (1979) early work. In her scrupulous attention, the element that a discourse keeps eyes peeled for is termed as "discourse focus", or simply "focus", and is an item the speaker wishes to make some predications about. In contrast, "actor focus", defined as the current agent in some events, plays a primary role in anaphora disambiguation. And finally, the "potential focus" refers to a list of alternate candidates for each focus (Sidner, 1979; 1981).

Furthermore, in order to eliminate the confusion brought about by the notion of "focus" in literature, a new term "center" rushes into the forefront of another strand of linguists like Joshi, Kuhn and Weinstein (Joshi, Kuhn, 1979; Joshi, Weinstein, 1981). Meanwhile, by their perspicacious classification, the "center" becomes two-fold: one is "Forward-looking center", *Cf* (U_n, *DS*), being roughly tantamount to Sidner's "potential foci"; another is "Backward-looking center", *Cb* (U_n, *DS*), and basically equals to the "discourse focus" (Sidner, 1979; Joshi, Weinstein, 1981).

Based on the two lines of work, a general picture of initial Centering Theory is presented (Grosz, Joshi, Weinstein, 1983; Grosz, Sidner, 1986; Brennan, Friedman, Pollard, 1987; Grosz, Joshi, Weinstein, 1995). For one thing, there are three layers in a discourse: (i) a linguistic structure, (ii) an intentional structure, and (iii) an attentional state/ focusing structure, all of which evolve as the discourse proceeds (Grosz, Sidner, 1986). Moreover, each discourse has two varieties of purpose: (i) a discourse purpose (*DP*), referring to the overall intention that underlies engaging in a particular discourse (*D*); and (ii) a discourse segment purpose (*DSP*), being singled out in each discourse segment (*DS*). For another thing, some related terms are further ameliorated by Grosz et al. (Grosz, Joshi, Weinstein, 1983; Grosz, Joshi, Weinstein, 1986; Grosz, Joshi, Weinstein, 1995). The "center" of an utterance, not sentence in isolation, refers to those entities being responsible for linking the current utterance (U_n, *DS*) with adjacent utterances (U_{n-1}/U_{n+1}, *DS*) (Grosz, Joshi, Weinstein, 1986; Grosz, Joshi, Weinstein, 1995). Furthermore, the local focusing process, that is, the process of identifying centered entities/centers, is labeled as "centering" (Sidner, 1979; Joshi, Weinstein, 1981). In Grosz et al.'s (Grosz, Joshi, Weinstein, 1983; Grosz, Sidner, 1986; Brennan, Friedman, Pollard, 1987; Grosz, Joshi, Weinstein, 1995) attempt at a classification of 'center' in an individual utterance (U_n, *DS*), there exist (i) a *Cf* (U_n, *DS*), namely, the set of "forward-looking centers", (ii) a single backward-looking center, *Cb* (U_n, *DS*), and (iii) a Preferred center, *Cp* (U_n, *DS*). The *Cb* (U_n, *DS*) and the set of *Cf* (U_n, *DS*) alike correspond to linguistically realized NPs in utterance (U_n, *DS*). In addition, some centering proposals apropos of the rules and constraints on centers are made clear by previous scholars.

Last but not least, the early centering framework also show some failings. Firstly, in the words of Grosz et al. (Grosz, Joshi, Weinstein, 1986; 1995), the mysterious yashmak of the relationship between centering and the generation of a discourse is no less not unveiled. Secondly, early work hardly scratches the surface of the problem that how to provide a unified account of zeros,

namely, implicit centers, within a discourse. Thirdly, the well-formedness of discourse coherence, as a focus of centering approach, is built upon the center transitions between two adjacent utterances. It means that this kind of coherence is borne out to be local, and hence it may be much wrong-footed when deliberating on whether there exists a coherence within a larger unit or not. Lastly, the initial version of centering model is outlined by way of English data, so the parameters settings, such as "discourse segment", "*Cf* ranking" and "utterance", may turn out to be infelicitous in other languages. In the meantime, in central papers such as Grosz, Joshi and Weinstein (1986; 1995), no algorithm is offered to compute these specific notions above, by which, however, most centering claims are articulated. Other than that, some follow-up empirical researches (e.g. Poesio, Stevenson, Di Eugenio, Hitzeman, 2004) have borne out that different ways of setting the parameters would affect the theory's claims.

All told, albeit admittedly incomplete, the early model of centering does provide a solid basis for follow-up researches regarding discourse coherence.

2. EMPIRICAL STUDIES OF CENTERING THEORY

Based on the centering model, the past couple of decades have seen a wealth of overseas and domestic researches with regard to the following issues prospering: what's the relation between discourse coherence and intrinsic complexity of certain inferences? How does the centering algorithm interact with the inference mechanism? How to provide an account for definite noun phrases and anaphoric expressions (especially the pronoun resolution) within a discourse? If we set the parameters in different ways, what is the effect on the theory's claims? How to set centering parameters in different languages? just to name a few. In this section, we will attend on the parametric studies and application studies of Centering Theory.

2.1 Parametric Studies of Centering Theory

In central papers such as Grosz et al.'s viewpoints (Grosz, Joshi, Weinstein, 1986; 1995), albeit incredibly important for centering claims, some specific concepts such as "utterance", "discourse segment", "ranking of *Cf*" and "realization" are not settled on. As a result, a reservoir of research efforts have been undertaken in order to arrive at a detailed specification for these notions. Poesio et al. (e.g. 2004), for instance, firstly view the Centering Theory as a parametric theory, and secondarily, with the aid of corpus and automatic analysis system, investigate the effect on the theory's claims of different ways of setting the parameters. Xu Yulong (2008), in a spirit similar to Poesio et al.'s (2004) analyses, extends previous four parameters into five: (i) utterance, (ii) pronoun in Rule 1, (iii) realization, (iv) ranking and (v) discourse segment. In addition, as well as being in the footsteps of Poesio et al.'s (2004) parametric approach, Chen Shuangshuang (2019) approvingly provides the sixth parameter, Rule 2, of Centering Theory.

2.1.1 Utterance (U_i) and Previous Utterance (U_{i-1})

Early scholars fail to speak volume for two puzzles: (i) "utterance" is deemed as an updating unit, so how to define the length of it? (ii) How to delimit an utterance unit that embodies the updates of centers? In order to crack the two hard nuts, much investigation of centering parameters has been proceeded.

Initially, the "utterance" is treated as a sentence, since a discourse is often composed of a host of simple sentences. Put another way, both the utterance (U_i) and previous utterance (U_{i-1}) are viewed as sentences. However, one cannot ignore that there are several variants of a sentence in naturally-occurring discourse. Meanwhile, there is a big question-mark hangs over the complex sentence/utterance that consists of multiple clauses.

Given that, Kameyama (1998) deems the complex sentences as pieces of subsentential 'utterance' units. In the words of Kameyama (1998), an utterance has better to be identified as a tensed clause, which can be further divided into conjuncts and adjuncts, and embodies a "permanent" update of local focus. In contrast, the tenseless subordinate clausal conjuncts and adjuncts, namely, embedded clauses, do not update the center. And a "permanent" update of local focus exists but would be "popped" immediately when the processing of current utterance comes to an end. All told, in Kameyama's (1998) notes, coordinate clauses and adjuncts are able to function as utterance (U_i) and previous utterance (U_{i-1}), while the embedded clauses fail to be an utterance (U_i).

However, this assumption, namely, identification of utterances with (tensed) clauses, is called into question by Miltsakaki (1999), who, based on the data from English and Greek, holds that the local focus is updated only after every sentence and that only the *Cf*s in the main clause are considered when establishing the *Cb*. The same sentiment is voiced by Suri, McCoy (1994), Cooreman, Sanford (1996) and Pearson et al. (Pearson, Stevenson, Poesio, 2000). In more detail, Pearson et al. (2000) argue that complement clauses where *Cf*s are introduced should be taken into the embedded clauses rather than main clauses. And Suri and McCoy (1994) further relegate adjunct clauses led by *before* and *after* to the sphere of embedded clauses. At the same time, Kameyama (1998) herself proceeds to specify the types of embedded clauses, and declares that the relative clause should fall under this group. Moreover, when Xu Yulong (2008) appeals to centering model to probe into the discourse anaphora resolution, he expresses a firm belief that the clauses introduced by the words like *think and believe* should be excluded in main clauses. In Xu's (2008) cognizance, although this kind of clauses can be main clauses in the

surface structure, they are always incapable of introducing an entity into the discourse, and merely indicate the information sources.

2.1.2 Realization

For the purpose of describing the relationship between the *Cb* (U_{n+1}, *DS*) and *Cf* (U_n, *DS*), Grosz et al. (1995) introduce two types of realization relations: *realizes* and *directly realizes*. Put differently, there are two ways where *U realizes a center C*. To be specific, a center turns out to be "directly realized" by an utterance if it is the semantic interpretation of a phrase in the utterance (Grosz, Joshi, Weinstein, 1995). And a center would be "indirectly realized" if the phrase in the utterance is an "associative reference" to the discourse entity. It means that an anaphoric expression refers to an entity that is somehow related to an object which has already been mentioned.

More technically, an utterance "directly realizes" an entity implicitly focused by an element of the *Cf* of the previous utterance. Consider the example (1) (from Poesio, 2004, p.317):

(1)
a. John walked towards *the house*.
b. The door was open.

The entities *John* and *the house* are directly realized in the utterance (1a) and *the door* is also directly realized in (1b). However, *the house* is indirectly realized in (1b) by virtue of its association with *the door*. Put another way, the complete form of the entity *the door* is *the door of the house*. *The door* expresses a functional relation whose argument, namely, *the house*, has been directly realized in the previous utterance. Furthermore, Grosz et al. (Gorsz, Joshi, Weinstein, 1995) assume that the ranking of *the door* is higher than *the house* in *Cf* (U_b). According to them, if (1b) is followed by a next utterance with '*it*' in the subject position, then '*it*' is more likely to cospecify *the door* rather than *the house*.

Based on the analyses above, a mini-conclusion can be arrived at. If the centering model only adopts *directly realization*, there would be no *Cb* in utterance (1b). On the contrary, if the model accepts both *directly realization* and *indirectly realization*, the entity *door* is able to function as *Cb* in utterance (1b). However, the two varieties of "realization" have not been spilled enough ink by early scholars.

Moreover, early research endeavors also deliberate on whether the empty realization is acceptable in a discourse or not. Some cross-linguistic studies have borne out that the empty realization is capable of counting as the realization of an entity in Chinese and Japanese. However, the confusion, whether or not the morphologically null element can count as a kind of realization in English, has not been approvingly mentioned in literature.

A third big headache is closely germane to the application of realization relations. Whether or not the first- and second-person noun phrases belong to the *Cf* list appears to be a tropical subject among scholars (Di Eugenio, 1998; Walker, 1993). However, only seldom lends itself to an exact elucidation.

2.1.3 The Ranking of the Set of *Cfs*

In order to make a better prediction for the *Cp*, a sheer number of researches have been centered on establishing the factors of *Cf* list ranking. In practice, as stated by Walker, Iida, and Cote (1994) and Walker, Joshi, Prince (1998), the factors affecting ranking may not be the same in all languages.

The thematic role is given primacy in Sidner's (1979; 1981; 1983) publications. Later, this view is beefed up by Stevenson et al. (1994; 2000) and Pearson et al. (2001), who insist that with certain verbs, the normal preference for subjects to rank higher than their objects is reversed. It means that objects are ranked higher than their subjects. Meanwhile, in transfer sentences, THEMEs are usually ranked higher than GOALs, which in turn are ranked higher than SOURCEs. And this ranking is often interwoven with other factors such as the order of mention, the animacy and the type of connective.

Besides, a common view is that the grammatical role rather than thematic role is a major determinant of the *Cf* list ranking (Kameyame, 1985, 1986; Grosz, Joshi, Weinstein, 1986, 1995). Accordingly, a ranking order in English can be provided: Subject > Object (s) > Other, in view of which, an entity sitting in the subject position will be highest ranked in *Cf*. And subjecthood is considered as a top priority, and objecthood is in second.

Stimulated by Kameyame (1985; 1986) and Grosz et al. (1986; 1995), Brennan et al. (1987), in terms of the grammatical relation of the subcategorized functions of the main verb, further distinguish the direct object from the indirect object and other subcategorized functions with adjuncts. They (1987) refine the version given by Grosz et al. (1986; 1995) as: Subject > Direct Object > Indirect Object > Other subcategorized elements > Adjuncts.

Based on the data from Japanese discourse, Walker et al. (Walker, Iida, Cote, 1994; 1996) incorporate EMPATHY and TOPIC into the ranking: Grammatical or Zero Topic > Empathy > Subject > Object 2 > Object > Others. Moreover, a slightly different ranking in Chinese discourse is provided by Wang Deliang (2004): Topic > Subject > Object > Others. As well as being cross-linguistic, Turan (1998) concentrates on those syntactic factors that are able to determine the most salient entity in Cf set in Turkish. The results suggest that subjecthood is a strong indicator of salience. However, if the thematic roles are used for ranking, Experiencer objects of psychological verbs would rank higher than their Theme subjects (Turan, 1998). Therefore, a modified version for Turkish *Cf* ranking is presented as: Empathy > Subject > Indirect Object > Direct Object > Others > Quantified Indefinite Subjects > Arbitrary Plural Null Pronominals.

In addition, some psycholinguistic researches (Hudson-D'Zmura, 1988; Gordon, Grosz, Gillion, 1993) further point out that both syntactic role and surface position can affect the ranking of an entity in the set of *Cf*. Other than that, a new factor of *Cf* list ranking, animacy, has been observed in Spanish by Taboada (2002; 2005; 2008) who brings forth the order of *Cf* list as below: Experiencer > Subject > Animate Indirect Object > Direct Object > Others > Impersonal / Arbitrary Pronoun. Then, proposed by Gernsbacher, and Hargreaves (1988), the fourth factor that determines *Cf* list ranking turns out to be the surface order. It is suggested that the first-mentioned discourse entity in a given utterance tends to be the most salient. Last but not least, the givenness hierarchy is also deemed as an important factor for determining the *Cp* and the entity which is predicated to be the center of attention in the next utterance. Strube and Hahn (1999), according to the degree of givenness of entity to hearers, the ranking is provided as follows: Hearer-old > Mediated > Hearer-new.

2.1.4 Pronouns in Rule 1

In central papers such as Grosz et al., "Rule 1" stipulates that no element in an utterance can be realized as a pronoun unless the backward-looking center, *Cb*, of the utterance is realized as a pronoun also (Grosz, Joshi, Weinstein, 1986; 1995). However, with regard to Rule 1, the puzzle of the *Cb* can be realized by what types of pronouns in English is often glimpsed by early linguists.

In English, there is no denying that the third-person singular pronoun must be the belonging of pronouns specified by Rule 1. Furthermore, some cross-linguistic researchers have demonstrated that there is a preference for realizing *Cb*s by zeros, namely, null pronouns, in some languages. Kameyama (1985; 1986) and Walker et al. (Wakler, Iida, Cote, 1994), for instance, pay close attention to Japanese zero pronominal binding and zero anaphora, and then suggest that zero pronouns are equivalent to the accented pronouns in English. Moreover, aided by the data from Turkish and Italian discourses, an attempt at a distinction between the null and overt pronouns in subject positions are made by Turan (1998) and Di Eugenio (1998), who hold the view that zero pronouns should also be covered by Rule 1.

Something also to note is that whether the *Cb*s can be realized by first- and second-person pronouns or not has long been inconclusive. In the meantime, a series of confusions noted by Poesio (2004) have continued to haunt linguists. Should an utterance in English count as verifying the rule if a *Cf* is preferentially realized as a third-person pronoun, and the *Cb* as a zero/trace? Or if the *Cb* is realized with a full NP, but a second *Cf* is realized with a demonstrative pronoun (Poesio, 2004)? And what about first- and second-person pronouns? Little light is shed on these headaches by previous research work.

2.1.5 Discourse Segmentation

A prominent viewpoint pertinent to centering framework is that a discourse is composed of a host of discourse segments with distinct intentions. However, the discourse intention structure is briefed by early scholars (Grosz and Sidner, 1986), and hence there is a lack of attention to details, which in turn influences their further segmentation.

For this reason, most previous research efforts of centering either overlooked segmentation or chose to identify segments by Walker's (1989) heuristics, which highlights considering every paragraph as a separate discourse segment, except when its first sentence contains a pronoun in subject position or a pronoun whose agreement features are not matched by any other *Cf* in the same sentence.

2.1.6 Rule 2

Rule 2 provides a typology of transitions, and underlines distinct transition states being used to measure the coherence of a discourse segment by stipulating that some transition types are preferred over others. Therefore, the utterances linked by center transitions showcase more coherence than those in terms of preserving the *Cb* over changing it and realizing it in a higher ranked position on the *Cf*. In short, Rule 2 is designed to dig deeper into the relationship between discourse coherence and the salience of semantic entities.

In the words of Grosz, Joshi and Weinstein (1986; 1995), the typology of transition states between two adjacent utterances is based on two factors as follows:

(2)
a. $Cb\ (U_i) = Cb\ (U_{i-1})$, or $Cb\ (U_{i-1}) = [?]$
b. $Cb\ (U_i) = Cp\ (U_i)$

In centering literature, based upon the factors in (2), the typology of transition states laid out in Table 1 is well known and overwhelming. The notation $Cb\ (U_{i-1}) = [?]$ is used for cases where there is no $Cb\ (U_{i-1})$, such as the utterance-initial position.

Table 1
Center transition states — Grosz, Joshi, and Weinstein (1995) version

	$Cb\ (U_i) = Cb\ (U_{i-1})$, or $Cb\ (U_{i-1}) = [?]$	$Cb\ (U_i) \neq Cb\ (U_{i-1})$
$Cb\ (U_i) = Cp\ (U_i)$	CONTINUE	SMOOTH-SHIFT
$Cb\ (U_i) \neq Cp\ (U_i)$	RETAIN	ROUGH-SHIFT

According to Grosz et al. (Gorsz, Joshi, Weinstein, 1986; 1995) and Brennan et al. (Brennan, Friedman, Pollard, 1987), the factor (2a) is often satisfied when the speaker pursues the local coherence, but there are two different cases. For one thing, if both the factors (2a) and (2b) holds in the meantime, then the two adjacent utterances are connected by a CONTINUE transition. In this case, the speaker has been talking about a particular entity and intends to proceed that entity in following utterances. For another thing, if the factor (2a) holds

but (2b) fails, then the two utterances are related by a RETAIN transition, which corresponds to the case where the speaker intends to get the centered entity updated in the next utterance and to signal this by realizing the current centered entity in a lower ranked position on the *Cf*.

In contrast, a SHIFT occurs when successive *Cb*s are not the same. That is, if the factor (2a) fails to hold, then the centered entity will get updated after every utterance. In this update, the neighboring utterances are linked by two types of SHIFT states, depending on whether the *Cb* (U_i) and *Cp* (U_i) are equal or not. If these two are equal, then the two utterances are connected by a SMOOTH-SHIFT transition, whereas if they are distinct, then the two utterances are related by a ROUGH-SHIFT transition.

According to Rule 2, the transition states are ordered in sequence with regard to their contributions to the coherence of discourse: CONTINUE > RETAIN > SMOOTH SHIFT > ROUGH SHIFT.

In terms of this ranking, Grosz et al. (Gorsz, Joshi, Weinstein, 1986; 1995) and Brenan et al. (Brennan, Friedman, Pollard, 1987) showcase their preference among sequences of transitions. For instance, a sequence of utterances which are connected by the transition state combinations of CONTINUE + CONTINUE is significantly preferred over other combinations like SHIFT + SHIFT.

Other than that, a few alternative classification schemes have been proposed. Kameyama (1986) provides a new transition type, Center Establishment (EST), which refers to the transition between an utterance without a *Cb* and an utterance with a *Cb*. However, Poesio et al. (2004) present a quite opposite picture: ZERO transition or NULL transition. This claim is motivated by evidences from their empirical studies on centering parameters. Furthermore, based on corpus analysis of English and Spanish causal conversations, Taboada and Wiesemann (2010) find that CONTINUE transition is always the most preferred transition, whereas ROUGH SHIFT is the least preferred. And the preference of RETAIN over SMOOTH SHIFT does not always hold. Therefore, they incorporate The ZERO transition and NULL transition as well as EST, and then ameliorate Rule 2 as: CONTINUE > ESTABLISH > (RETAIN, SMOOTH SHIFT) > ROUGH SHIGT > ZERO > NULL.

Then, based on inference load between adjacent utterances, Strube and Hahn (1999), pursue two types of transition pairs, that is, cheap transition and expensive transition, which hold for three immediately successive utterances. To be specific, if the backward-looking center of the current utterance is correctly predicated by the preferred center of the immediately preceding utterance, then the transition pair is cheap. If not, then it is expensive. Thus consider the revised definitions of transition states below:

Table 2
Center transition states — Strube and Hahn (1999) version

$Cb(U_i) = Cb(U_{i-1})$, or $Cb(U_{i-1}) = [?]$		$Cb(U_i) \neq Cb(U_{i-1})$
$Cb(U_i) = Cp(U_i)$ and $Cp(U_i) = Cp(U_{i-1})$	CONTINUE	SMOOTH-SHIFT
$Cb(U_i) = Cp(U_i)$ and $Cp(U_i) \neq Cp(U_{i-1})$	EXP-CONTINUE	EXP-SMOOTH-SHIFT
$Cb(U_i) \neq Cp(U_i)$	RETAIN	ROUGH-SHIFT

Then, based on the revised transition types, they refine the Rule 2 as follows:

(3)
Rule 2 (Revised by Strube and Hahn, 1999):
Cheap transition pairs are preferred over expensive ones.

Laurel Fais (2004) proceeds a centering analysis of the corpus of Japanese e-mail and notes that every utterance, not just U_{i-1}, evokes inferable centers. This kind of center refers to the entity that is not expressed at the surface level of an utterance, or cannot be immediately recoverable from the subcategorization properties of the verb, so it turns out to be only inferable from the discourse situation. Moreover, in his article (Laurel Fais, 2004), lexical cohesion is proposed as a well-defined notion, based on which two new kinds of center transitions, COHESIVE and COMPLETE SHIFT, are provided. With the standard transition states defined in the left side and the revised version in the right side, Table 3 contains a complete overview of the transition pairs. Only those whose second transition fulfills the criterion $Cp\ (U_i) = Cp\ (U_{i-1})$ are labeled as "cheap".

Table 3
Center transition states — Laurel Fais (2004) version

	$Cb(U_i) = Cb(U_{i-1})$ OR $Cb(U_{i-1}) = [?]$ and $Cb(U_i) \neq [?]$	$Cb(U_i) \neq Cb(U_{i-1})$	$Cb(U_i) = [?]$	
$Cb(U_i) = Cp(U_i)$	CONTINUE	SMOOTH SHIFT	COHESIVE	$\exists Cf(U_i) \approx Cf(U_{i-1})$
$Cb(U_i) \neq Cp(U_i)$	RETAIN	ROUGH SHIFT	COMPLEMENT SHIFT	$\sim(\exists Cf(U_i) \approx Cf(U_{i-1}))$

(3)
Rule 2 (Revised by Laurel Fais, 2004):
CONTINUE > COHESIVE > RETAIN> SMOOTH SHIFT > ROUGH SHIFT > COMPLETE SHIFT

2.2 Application Studies of Centering Theory

A fruitful body of researches have bubbled up to achieve centering application. Early centering papers (Brennan, Friedman, Pollard, 1987; Strube and Hahn, 1999; Tetreault, 2001) are mainly immersed in the anaphora resolution based on the algorithm given by Brennan et al. (Brennan, Friedman, Pollard, 1987). Domestically, Xu Yulong, Duan Manjuan et al. (2009; 2008) undertake several systematic researches on the effects of difference

parameter settings on the anaphora resolution in Chinese. Moreover, many papers also work at natural language processing including sentence planning (Dale, 1992; Henschel, Cheng, Poesio, 2000) and text planning (Kibble, Power, 2000; Karamanis, 2003). As well as being popular, some authorities (e.g. Kameyama, 1985; Walker, Iida, Cote, 1994; Di Eugenio, 1998; Turan, 1998; Gordon, Grosz, Gillion, 1993) have their sights focused on the cross-linguistic and psychological studies of Centering Theory.

CONCLUSION

To wrap up, fueled by cementing the foundation of subsequent research endeavors and helping readers get a picture of the centering framework, the present author zeroes in on a general review of Centering Theory from central centering claims, on one hand, and from empirical researches, on the other hand. From above review, the most prominent point that can be lifted the veil here is that several centering claims are articulated in terms of notions which are only partially specified, such as "utterance", "discourse segmentation", "realization of centers", or "ranking". Notwithstanding more detailed specifications having been arrived at by mounting-up research efforts over the past decades, no conclusive algorithm has been very much in the foreground to compute these notions. Also, a big question-mark still hangs over the parameter settings in some overlooked languages as well as over the effects of different parameter settings in one same language, which are waiting to see breakthroughs.

REFERENCES

Brennan, S. E., Friedman, M. W., & Pollard, C. J. (1987). A centering approach to pronouns. *Proceedings of the 25th ACL*, 155-162.

Chen, S. S. (2019). Centering theory: A cross-linguistic study. *Foreign Languages in China*, (4), 55-64.

Cooreman, A., & Sanford, T. (1996). Focus and syntactic subordination in discourse. Research Paper no. RP-79, University of Edinburgh, HCRC.

Dale, R. (1992). *Generating referring expressions*. Cambridge, MA: MIT Press.

Di Eugenio, D. (1998). Centering in Italian. In M. A. Walker, A. K. Joshi & E. F. Prince (Eds.), *Centering theory in discourse*. Oxford: Oxford University Press.

Duan, M. J., Xu, Y. L., & Fu, X. J. (2009). Effects of centering parameter setting of *Cf*-ranking on Chinese anaphora resolution. *Journal of Foreign Languages*, (3), 20-27.

Fais, L. (2004). Inferable centers, centering transitions, and the notion of coherence. *Computational Linguistics*, (2), 119-150.

Gernsbacher, M. A., & Hargreaves, D. (1988). Accessing sentence participants: The advantage of first mention. *Journal of Memory and Language*, (27), 699-717.

Gordon, P. C., Grosz, B. J., & Gillion, L. A. (1993). Pronouns, names, and the centering of attention in discourse. *Cognitive Science*, (17), 311-348.

Grosz, B. J. (1977). *The representation and use of focus in dialogue understanding* (Ph. D. thesis). Stanford University.

Grosz, B. J., & Sidner, C. L. (1986). Attention, intentions, and the structure of discourse. *Computational Linguistics*, (3), 175-204.

Grosz, B. J., Joshi, A. K., & Weinstein, S. (1983). Providing a unified account of definite noun phrases in discourse. *Proceedings of the ACL*, 44-50.

Grosz, B. J., Joshi, A. K., & Weinstein, S. (1986). *Towards a computational theory of discourse interpretation*. Unpublished manuscript.

Grosz, B. J., Joshi, A. K., & Weinstein, S. (1995). Centering: A framework for modeling the local coherence of discourse. *Computational Linguistics*, (2), 202-225.

Henschel, R., Cheng, H., & Poesio, M. (2000). Pronominalization revisited. *Proceedings of the 18th COLING*.

Hudson-D'Zmura, S., & Tanenhaus, M. M. (1998). Assigning antecedents to ambiguous pronouns: The role of the center of attention as the default assignment. In M. A. Walker, A. K. Joshi & E. F. Prince (Eds.), *Centering theory in discourse*. Oxford: Oxford University Press.

Joshi, A. K., & Kuhn, S. (1979). Centered logic: The role of entity centered sentence representation in natural language inferencing. *Proceedings of the IJCAI*, 435-439.

Joshi, A. K., & Weinstein, S. (1981). Control of inference: Role of some aspects of discourse structure—centering. *Proceedings of the IJCAI*, 385-387.

Kameyama, M. (1985). *Zero Anaphora: The case of Japanese* (Ph. D, thesis). Stanford University.

Kameyama, M. (1986). A property-sharing constraint in centering. *Proceedings of the ACL-86*, 200-206.

Kameyama, M. (1998). Intra-sentential centering: A case study. In M. A. Walker, A. K. Joshi & E. F. Prince (Eds.), *Centering theory in discourse*. Oxford: Oxford University Press.

Karamanis, N. (2003). *Entity coherence for descriptive text structuring* (Ph. D. thesis, Informatics). University of Edinburgh.

Kibble, R., & Power, R. (2000). An integrated framework for text planning and pronominalization. *Proceedings the of INLG*.

Miltsakaki, E. (1999). Locating topics in text processing. *Proceedings of the CLIN*, 127-138.

Pearson, J., Stevenson, R., & Poesio, M. (2000). Pronoun resolution in complex sentences. *Proceedings of the AMLAP*.

Pearson, J., Stevenson, R., & Poesio, M. (2001). The effects of animacy, thematic role, and surface position on the focusing of entities in discourse. In M. Poesio (Ed.), *Proceedings of the First SEMPRO*. Edinburgh: University of Edinburgh.

Poesio, M. (2004). The MATE/GNOME scheme for anaphoric annotation, revisited. *Proceedings of the SIGDIAL*.

Poesio, M., Stevenson, R., Di Eugenio, B., & Hitzeman, J. (2004). Centering: A parametric theory and its instantiations. *Computational Linguistics*, (3), 309-363.

Sidner, C. L. (1979). *Towards a computational theory of definite anaphora comprehension in English discourse* (Ph.D. thesis). MIT.

Sidner, C. L. (1981). Focusing for interpretation of pronouns. *Computational Linguistics*, (4), 217-231.

Sidner, C. L. (1983). Focusing in the comprehension of definite anaphora. In M. Brady & R. C. Berwick (Eds.), *Computational Models of Discourse*. Cambridge, MA: MIT Press.

Stevenson, R. J., Rosalind, A. C., & Kleinman, D. (1994). Thematic roles, focus, and the representation of events. *Language and Cognitive Processes*, (9), 519-548.

Stevenson, R., Alistair, K., Jon, O., Scott, M. (2000). Interpreting pronouns and connectives: Interactions between focusing, thematic roles and coherence relations. *Language and Cognitive Processes*, (15), 225-262.

Strube, M. & Hahn, U. (1999). Functional centering—Grounding referential coherence in information structure. *Computational Linguistics*, (3), 309-344.

Suri, L. Z., & McCoy, K. F. (1994). RAFT/RAPR and centering: A comparison and discussion of problems related to processing complex sentence. *Computational Linguistics*, (2), 301-317.

Taboada, M. & Wiesemann, L. (2010). Subjects and topics in conversation. *Journal of Pragmatics*, (42), 1816-1828.

Taboada, M. (2002). Centering and pronominal reference: In dialogue, in Spanish. *Proceedings of the 6th Workshop on the Semantics and Pragmatics of Dialog, EDILOG*, 177-184.

Taboada, M. (2005). Anaphoric terms and focus of attention in English and Spanish. *Pragmatics and Beyond New Series*, 140-197.

Taboada, M. (2008). Reference, centers and transitions in spoken Spanish. *Reference and Reference Processing*, 176-215.

Tetreault, J. R. (2001). A corpus-based evaluation of centering and pronoun resolution. *Computational Linguistics*, (4), 507-520.

Turan, U. (1998). Ranking forward-looking centers in Turkish: Universal and language-specific properties. In M. A. Walker, A. K. Joshi, & E. F. Prince (Eds.), *Centering theory in discourse*. Oxford: Oxford University Press.

Walker, M. A. (1989). Evaluating discourse processing algorithms. *Proceedings of ACL-89*, 251-261.

Walker, M. A. (1993). Initial contexts and shifting centers. *Proceedings of the Workshop on Centering*.

Walker, M. A., Iida, M., & Cote, S. (1994). Japanese discourse and the process of centering. *Computational Linguistics*, (2), 193-232.

Walker, M. A., Joshi, A. K., & Prince, E. F. (1998). Centering in naturally occurring discourse: An overview. In M. A. Walker, Joshi, A. K., & Prince, E. F. (Eds.), *Centering theory in discourse*. Oxford: Oxford University Press.

Wang, D. L. (2004). Zero anaphora resolution in Chinese: A study based on Centering Theory. *Modern Foreign Languages*, (4), 350-359.

Xu, Y. L. (2008). A parametric approach to centering theory. *Contemporary Linguistics*, (3), 225-236.

Xu, Y. L., Duan, M. J., & Fu, X. J. (2008). Effects of centering parameter setting of “utterance” and “R1-pronoun” on Chinese anaphor resolution. *Modern Foreign Languages*, (2), 111-120.