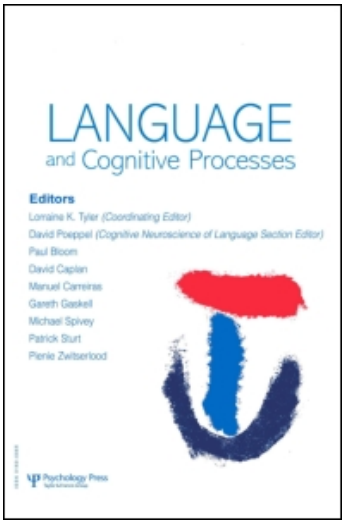

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Constraints on ontology changing complexation processes: Evidence from event-related brain potentials

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CNL Constraints on ontology changing complexation processes: Evidence from event-related brain potentials

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This paper investigates complex anaphoric reference (i.e., when an anaphor refers to a propositionally structured referent). Complex anaphors (e.g., *this process, this event*) differ in their ontological feature setup, and the ontological type assigned to a referent can change due to the lexical meaning of the complex anaphor. Previous research has proposed that such changes have to comply with an ontological 'abstractness constraint' restricting the direction of ontological change. We present an event-related potential study that provides evidence that violations of the abstractness constraint result in processing costs. The data reveal that violating this constraint by shifting the referent towards a less abstract ontological type elicits an enhanced N400, while reduction of ontological features towards a more abstract type exerts no extra processing demands. The data indicate that the abstractness constraint affects real-time sentence comprehension and that different ontological types are implicationally related.

Keywords: Complex anaphors; Ontology; Reference; Language comprehension.

Language comprehension depends to a large degree on successful identification of referents. To this end, anaphoric expressions are not only used to

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refer to objects and individuals, but they can also refer to propositionally structured referents (such as events, processes, facts, states, or propositions). Nominal expressions that refer to situations and other propositionally structured complex entities are called 'complex anaphors'. Like all kinds of anaphors, they reactivate referents that have been mentioned by antecedent expressions in prior discourse. Yet in addition to the reactivation of previously introduced information, complex anaphors establish their referents as condensed and stable discourse entities, i.e., they introduce a nominal expression for an entire proposition. Therefore, complex anaphors are important means of information flow and textual coherence. Consider the following example:

(1) *Nicolas Sarkozy and Carla Bruni got married.*
  (a) This/This happening was just reported on TV.
  (b) This fact/This lie was just reported on TV.
  (c) This misalliance is a catastrophe for the French nation.
  (d) This godsend is a fortune for the French nation.

The underlined expressions in (1a–d) are complex anaphors referring to second- or third-order entities in the sense of Lyons' (1977, 1989) terms.[1] They condense a propositionally structured antecedent (in italics) to a nominal expression. Thereby, their complex referents are reified to 'things' (i.e., nominal objects) and become easily manageable in the following discourse (see Consten & Knees, 2008; Consten, Knees, & Schwarz-Friesel, 2007; Schwarz-Friesel, Consten, & Knees, 2004). Researchers have heterogeneously denoted anaphoric reference to complex objects as *abstract object anaphora* (Asher, 1993, 2000), as well as *extended reference* and *reference to fact* (Halliday & Hasan, 1976), *situational anaphora* (Fraurud, 1992), or *discourse deixis* (Webber, 1991).

Reference to complex objects has been analysed extensively in formal semantics (Asher, 1993, 2000; Davidson, 1967; Higginbotham, 2000; Parsons, 1990). In spite of differences in the ontological categorisation of such referents (cf. Dowty, 1979; Kim, 1969, 1976; Vendler, 1967; as well as Asher, 1993, 2000; Maienborn, 2003), there seems to be an agreement among semanticists that such a categorisation can be made in terms of entailment relations between different ontological types, yielding a linear

[1] Lyons (1977) defines 'first order entities' as physical objects that *exist* continually in space and time independent from their verbalisation. 'Second order entities' are spatio-temporal events, situations, or processes (that *take place, happen*) which have no continuity, but a temporal duration. These referents can be mere verbal constructions (cf. Lyons, 1989). 'Third order entities' (concepts, propositions) are always verbal constructions and independent from space and time.

hierarchy that indicates increasing 'abstractness'. Crucially, in these approaches, abstractness is defined in terms of boundedness to physical features of the reference situation (and should not be confused with the abstract-concrete distinction made in lexical-semantics and associated differences in imaginability). Accordingly, abstractness is understood with respect to the boundedness of complex referents to points in time, duration, space, agents, and worlds. In the following, we use the ontological categories as indicated in Figure 1 (cf. Maienborn, 2003; for a detailed discussion see Consten & Knees, 2008).

An increase in abstractness comes along with a decrease in boundedness. Since events are defined as spatio-temporal entities with specified beginnings and endings as well as certain agents, they have a high degree of boundedness and are the 'least abstract' complex entities. Processes, in contrast, lack the physical feature of having specified endings – encoded as [-telic] in Figure 1 – and are therefore considered more abstract (i.e., less specified for features of boundedness). In case a spatio-temporal entity is linguistically described as an event, the description focuses on its result – indicated by the feature [+ telic] in Figure 1 – (see (2) for an example), whereas speaking about an entity as a process emphasises its temporal duration without envoking a particular enpoint (see (3) and (4)). This shows that the ontological categorisation of complex referents is not (or, at least, not always) a property of the referent itself but of its verbalisation.

(2) She flew from New York to Washington (so she is in Washington now).
(3) She flew all night.
(4) She flew all night to get to Washington (but it is unknown if she arrived there).

States are more abstract than events and processes, as they are not dynamic and telic, but are bound to experiencers within a certain time interval. Moreover, they can be bound to certain locations (see (5)) or not (see (6)) (cf.

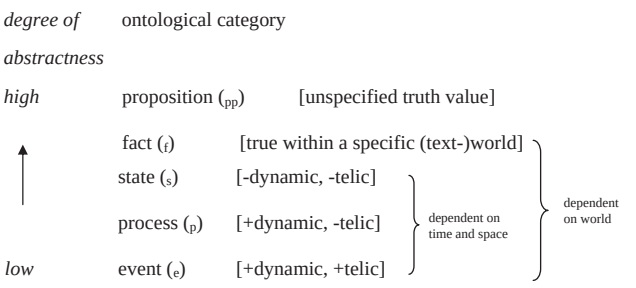

Figure 1. Abstractness scale.

Maienborn, 2003, 2004). Facts and propositions are even more abstract. While facts are bound to a certain (text-)world, namely the world in which their proposition is true (cf. Asher, 2000; Maienborn, 2003), propositions are not bound within a certain world. They are mere possibilities and thus unspecified with respect to truth values.

(5) In New York, she is happy.
(6) ? In New York, she is blond.

Regarding the ontological type of the referent, complex anaphors allow for two different referential processes: they either confirm or shift the ontological type of their referent. In the former case, complex anaphors reactivate the referent of the antecedent and confirm the ontological type assigned by the antecedent (e.g., a process anaphor refers to a process antecedent (**p**←**p**), as exemplified in (7a)); in the latter case, they shift the ontological type of the referent to a *more abstract one* (e.g., referring with a state anaphor to a process (**p**←**s**), which means that the process referent is reactivated as a state referent – see (7b)).

(7) *The government has been discussing the reduction of subsidies for days without any result* $_{p}$.
  (a) The opposition is outraged about this never ending process $_{p}$.
  (b) The opposition is outraged about this stagnancy $_{s}$.

According to Consten et al. (2007), ontological changes are restricted by the following 'abstractness constraint': the complex anaphor cannot shift the ontological type of the referent to a discourse entity that is *less abstract* than the ontological type assigned by the antecedent (e.g., an event anaphor cannot pick up a process antecedent). Accordingly, an event anaphor such as *this event* in (8) cannot pick up a more abstract referent (e.g., **p**←***e**). This constraint has been generalised as in (9).

(8) *The earth turns about the sun* $_{p}$. This $_{p}$/This process $_{p}$/This state $_{s}$ will presumably last for $7 \cdot 10^9$ years. This fact $_{f}$ is well-known since Middle Ages. Researchers of the Vatican were not allowed to examine this possibility $_{pp}$/*this event $_{e}$.
(9) Abstractness constraint:
  * x←y if x > y ('if x is higher on the abstractness scale than y, where x represents the ontological type assigned by the antecedent and y that of the anaphor')

Empirical evidence for this constraint comes from Consten et al. (2007) who conducted corpus analyses on ontological change and its constraints.

Within a set of 60 lexical complex anaphors taken from the *TIGerKorpus* (a German newspaper corpus on the basis of the *Frankfurter Rundschau*), there were no violations of the abstractness constraint. Furthermore, the authors tested if ontological change was a frequent function of complex anaphors and found that only 30 out of 60 lexical complex anaphors evoked an ontological change, most of them marking referents as 'abstract objects' (Asher, 1993), i.e., facts and propositions (see General discussion).

In the present research, we were interested in the real time comprehension of anaphoric 'complexation' processes (i.e., the construction of a complex anaphor). Our aims were two-fold. First, we sought to shed light on the nature of the underlying cognitive mechanisms that cooperate during anaphoric complexation. Second, we wanted to test the psychological reality of the abstractness constraint which predicts that ontological change to a more abstract ontological type is licensed by the language system, while a shift to a less abstract type violates the referential principle. These questions were approached through event-related brain potential measures (ERPs).

ANAPHORIC PROCESSING AND ERPS

Previous research utilising ERPs has identified the N400-signature (a negative-going potential peaking between 300 and 600 ms after the onset of the eliciting event and showing a centro-parietal scalp distribution) as a correlate of lexical-semantic processing at the word, sentence and textual level (cf. Kutas, Van Petten, & Kluender, 2006 for an overview). The amplitude of the N400 has furthermore been characterised as an indicator for the difficulty of establishing an anaphoric relation (cf. e.g., Burkhardt, 2005, 2006; Streb, Rösler, & Hennighausen, 1999; Swaab, Camblin, & Gordon, 2004). A large body of literature discusses N400 effects with respect to accessing and retrieving lexical-semantic features from long-term memory (see for instance the review by Kutas and Federmeier, 2000 who discuss the N400 with respect to facilitation and activation of semantic networks). In this view, the amplitude of the N400 increases as a function of contextual support or expectation, i.e., the less expected or facilitated a critical word is within a given context (e.g., word list, sentence, discourse context), the more enhanced is the N400-amplitude. In particular, full or partial feature overlap in repetition and semantic priming respectively modulates the N400 signature (cf. e.g., Rugg, 1985; Weisbrod, Kiefer, Winkler, Maier, Hill, Roesch-Ely, & Spitzer, 1999). The fine-grained nature of these retrieval processes is further evidenced by studies that show that lexical-semantic category features are accessed in such a way that overlapping category information between an anticipated and an actually presented word yield a reduction in the N400-amplitude; for instance in (10), the unexpected, but

category feature matching ending *pines* elicited a smaller N400-amplitude in comparison to *tulips* (from Federmeier & Kutas, 1999a).

(10) They wanted to make the hotel look more like a tropical resort. So along the driveway, they planted rows of **palms/pines/tulips**.

While many early ERP studies concentrated on violation or priming paradigms and showed that semantic violations or unpredictability elicit a pronounced N400, more recent research suggests that the amplitude of the N400 also rises as a function of increasing integration difficulty with previously introduced information. Integration difficulty may for instance arise in the absence of an identity relation. Burkhardt (2006) investigated the comprehension patterns associated with direct anaphors (i.e., establishing identity relations) (11.a), indirect anaphors (11.b), and discourse-new expressions (11.c) and found that the more difficult the anaphoric process is, the more enhanced is the amplitude of the N400.

(11) a. Direct anaphor:
Tobias besuchte einen Dirigenten in Berlin. Er erzählte, dass **der Dirigent** sehr beeindruckend war. [German]
'Tobias visited a conductor in Berlin. He said that **the conductor** was very impressive.'

(11) b. Indirect anaphor:
Tobias besuchte ein Konzert in Berlin. Er erzählte, dass **der Dirigent** sehr beeindruckend war.
'Tobias visited a concert in Berlin. He said that **the conductor** was very impressive.'

(11) c. New referent:
Tobias unterhielt sich mit Nina. Er erzählte, dass **der Dirigent** sehr beeindruckend war.
'Tobias talked to Nina. He said that **the conductor** was very impressive.'

Establishing an identity relation in (11.a) elicited the least pronounced N400; recruiting inferential knowledge to form an indirect anaphoric relation between *concert* and *conductor* in (11.b) evoked a more enhanced N400; and the most pronounced N400 emerged in the absence of a potential referent in the immediate context (11.c). In addition to N400-modulations for processing demands during dependency formation, a late positive deflection emerged whenever a new discourse referent had to be established in discourse representation (11.b/c). This positivity is interpreted as a marker of discourse complexity, which increases when new discourse referents are added to the mental representation or when discourse information must be updated and

reanalysed. Here, we do not elaborate on this ERP component any further, since these kinds of discourse complexity effects are not manipulated in the present experiment (but see Burkhardt 2006, 2007 for further discussion of this discourse process). Moreover, reasons that reach beyond the lexical-semantic properties of a referent may account for enhanced integration demands (reflected in N400-modulations), such as when the distance between the antecedent expression and the anaphor increases (e.g., Streb, Hennighausen, & Rösler, 2004) or when the thematic role of the antecedent and its anaphor differ (e.g., Streb et al., 1999). N400-modulations during anaphoric processing have further been reported as a function of the definiteness marking of the antecedent – all other things being equal (12.b >12.a) (Roehm & Burkhardt, 2008). These findings are more easily explained by an integration view of the N400, since the lexical parameters are kept constant, while other features associated with referential prominence are varied.

(12) a. Indefinite antecedent:
Im Herbst bewunderte eine Kellnerin einen Reporter. Damals war **die Kellnerin** wirklich sehr einsam. [German]
'In the fall, a waitress admired a reporter. At that time, **the waitress** was indeed very lonely.'

(12) b. Definite antecedent:
Im Herbst bewunderte die Kellnerin den Reporter. Damals war **die Kellnerin** wirklich sehr einsam.
'In the fall, the waitress admired the reporter. At that time, **the waitress** was indeed very lonely.'

With respect to the processing of complex anaphors, Marx, Bornkessel-Schlesewsky, and Schlesewsky (2007) compared complex anaphors (13.a) to anaphors that have noun phrase antecedents and refer to concrete objects (13.b). They found no N400-differences as a function of anaphor type. This indicates that no additional processing cost is exerted by the complexation process required for the integration of *this accident* in (13.a) and that the core anaphoric process of mapping an expression onto a previously introduced entity is indistinguishable with respect to whether it involves a concrete object as in (13.b) or a propositionally structured entity as in (13.a).

(13) a. Complex anaphor:
Obwohl die Titanic als unsinkbar galt, *ging sie unter*. **Dieses Unglück** wurde sogar verfilmt. [German]
'Although the Titanic was said to be unsinkable, *it went down*. **This accident** was even filmed.'

(13) b. First order noun phrase anaphor:
Obwohl die Titanic als unsinkbar galt, ging *sie* unter. **Dieses Schiff** war ein fahrendes Luxushotel.

> 'Although the Titanic was said to be unsinkable, *it* went down. **This ship** was a swimming luxury hotel.'

In the following investigation, which draws on a questionnaire study eliciting offline ratings of the different complexation processes as well as time-sensitive online measures, we were specifically interested in the processes underlying anaphoric complexation that involve shifts in ontological type. In accord with the abstractness constraint, we predicted that ontological reduction to a more abstract type should be permitted during anaphoric processing, while reference establishment via a less abstract ontological type infringes the abstractness constraint – because ontological features that are not specified by the antecedent cannot be (re)constructed. This violation was hypothesised to engender an enhanced N400-signature. In contrast, whether the permissible ontological change demands additional processing resources is subject to further scrutiny. If the different types in the abstractness hierarchy are implicationally related – i.e., a certain abstract type carries specific ontological features (like boundedness to space, time and agents) and more abstract types represent reductions of these features – then no extra processing cost should be exerted by ontological reduction. However, if changing the ontological type is generally costly, both shifts should show a pronounced negativity relative to complexation by maintaining the ontological type.

The underlying processes could be interpreted with respect to the lexical-semantic view of the N400 as well as with respect to the integration view, since the featural set up of the entities involved in anaphoric complexation and the complexation process itself are intimately intertwined. Accordingly, the processing of a certain proposition (here, the context sentence) could preactivate a set of ontological features, and the violation of the abstractness constraint would then yield a mismatch with preactivated features. Similarly, establishing a complex anaphoric relation should be encumbered or blocked when features of the anaphor cannot be matched with features of the potential antecedent. However, based on previous findings from referential processing that have demonstrated immediate effects of discourse integration with respect to the computation of prominence features, we expect to tap into integration processes, and thereby to assess the role of ontological features as it pertains to dependency formation.

MATERIAL CONSTRUCTION

The critical stimuli were constructed in 120 sets of the three conditions exemplified in (14) below. The initial context sentence of each set described a process, which was referred to by means of a complex anaphor in the

subsequent target sentence. The three conditions varied with respect to the ontological type of the complex anaphor, representing (a) a process, (b) a state, or (c) an event. Crucially, as discussed above, maintaining the ontological status of the referent (**p←p**) – as in (14.a) or using a more abstract ontological type (i.e., a state anaphor for a process (**p←s**) as in (14.b)) are acceptable complexation processes. In contrast, changing the ontological status towards an ontological category with a lower degree of abstractness – as is the case in (14.c) where a process is picked up by an event anaphor (**p←*e**) – reflects a violation of the abstractness constraint.

(14) a. **Process – Process Anaphor (p←p):**
Die Nilbarsche im Viktoriasee vernichten nach und nach die meisten Buntbarscharten.
The Nile perch in Lake Victoria destroy gradually the most cichlid species
The Nile perch in Lake Victoria gradually destroy most of the cichlid species.
Naturschützer beobachten **diese Entwicklung** heute mit großer Besorgnis.
Conservationists observe this development today with great apprehension
*Conservationists observe **this development** nowadays with great apprehension.*

b. **Process – State Anaphor (p←s):**
Die Nilbarsche im Viktoriasee vernichten nach und nach die meisten Buntbarscharten.
The Nile perch in Lake Victoria destroy gradually the most cichlid species
The Nile perch in Lake Victoria gradually destroy most of the cichlid species.
Naturschützer beobachten **dieses Phänomen** heute mit großer Besorgnis.
Conservationists observe this phenomenon today with great apprehension
*Conservationists observe **this phenomenon** nowadays with great apprehension.*

c. **Process – *Event Anaphor (p←*e):**
Die Nilbarsche im Viktoriasee vernichten nach und nach die meisten Buntbarscharten.
The Nile perch in Lake Victoria destroy gradually the most cichlid species
The Nile perch in Lake Victoria gradually destroy most of the cichlid species.

> #Naturschützer beobachten **dieses Ereignis** heute mit großer Besorgnis.
> Conservationists observe this event today with great apprehension
> #*Conservationists observe* ***this event*** *nowadays with great apprehension.*

All complex anaphors were selected on the basis of various conceptual criteria (as for instance discussed in Consten & Knees, 2008; Herweg, 1990; Maienborn, 2003). These criteria were guided by typical semantic notions traditionally associated with the different ontological types and included for instance durativity for processes (e.g., processes allow for a durative adverbial such as 'for three minutes'), permanence at any given time for states, and telicity for events (e.g., events may happen 'three times', but cannot take place 'for three minutes' – unless for instance used in an iterative manner). As illustrated in Figure 1 above, the three ontological types investigated here differ in terms of durativity [± dynamic], telecity [± telic], and dependence on time, space, and worlds. The first two features suffice to dissociate the three types: events are [+ dynamic, + telic], processes are [+ dynamic, -telic], and states are [-dynamic, -telic]. Accordingly, duration expressions serve as diagnostics for [+ dynamic] and numeral adverbials like 'three times' or time frame adverbials are only allowed with [+ telic] expressions. These diagnostics were used to identify complex anaphoric expressions for the three critical conditions. In particular, processes and events are defined in terms of their temporal duration and they are considered to consist of chronologically ordered subevents; as a consequence, following Maienborn (2003), they can be combined with a durative predicate such as 'to last for three years' or 'to happen' as in (15.a) and (15.b). States in contrast are static and thus do not allow the combination with a duration expression (15.c). Similarly, processes and events can be modified by the manner adverbs 'slow' or 'fast', again, emphasising the duration, while states never allow such a modification (16). Since events have an inherent endpoint and are oriented towards certain results (i.e., are telic), they can be specified by adverbials like 'three times', 'many times'/'frequent', 'often', and so on indicating the repetitiveness of the respective event (17), or by time frame adverbials such as 'within three hours' (18); in contrast, combining these particular adverbials with process or state expressions – which are not defined in terms of certain results or with respect to a beginning and an endpoint – prompts a clash between different temporal requirements, which yields an anomalous interpretation or possibly requires enriched composition and the drawing of additional inferences that demand a reinterpretation towards an event reading (as for instance discussed in Moens and Steedman, 1988; the fact that enrichment towards another ontological type may take

place in certain contexts is indicated with # below, but does not affect the anaphoric processes investigated here). The four diagnostics are illustrated in (15)–(18) for event expressions (a), process expressions (b), and state expressions (c).

(15) **Test for Durativity ([+dynamic] for events and processes and [-dynamic] for states)**
   a. Dieses Ereignis/Diese Begebenheit passierte, während ich in Urlaub war.
   b. Dieser Prozess/Diese Entwicklung passierte, während ich in Urlaub war.
   c. *Dieser Umstand/Dieses Phänomen passierte, während ich in Urlaub war.
   *a.{This event/This incident} b.{This process/This development} *c.{This state/This phenomenon} happened while I was on vacation.*

(16) **Test for Durativity ([+dynamic] for events and processes and [-dynamic] for states)**
   a. das schnelle Ereignis/die schnelle Begebenheit
   b. der schnelle Prozess/die schnelle Entwicklung
   c. *der schnelle Umstand/das schnelle Phänomen
   *a. the fast event/the fast incident b. the fast process/the fast development *c. the fast state/the fast phenomenon*

(17) **Test for Telicity ([+telic] for events, [-telic] for processes and states)**
   a. das häufige Ereignis/die häufige Begebenheit
   b. #der häufige Prozess/die häufige Entwicklung
   c. #der häufige Umstand/das häufige Phänomen
   a. the frequent(ly occurring) event/the frequent incident #b. the frequent process/the frequent development #c. the frequent state/the frequent phenomenon

(18) **Test for Telicity ([+telic] for events, [-telic] for processes and states)**
   a. Dieses Ereignis/Diese Begebenheit endete innerhalb drei Stunden.
   b. #Dieser Prozess/Diese Entwicklung endete innerhalb drei Stunden.
   c. #Dieser Umstand/ Dieses Phänomen endete innerhalb drei Stunden.
   a.{This event/This incident} #b.{This process/This development} #c.{This state/This phenomenon} has ceased within three hours.

The complex anaphors were further matched for length and frequency of occurrence across the three critical conditions (based on *Wortschatz Universität Leipzig*) ($F < 1$). Table 1 provides mean values for various characteristics of the anaphoric expressions. The complex anaphors always followed the main verb in the target sentence, and they were introduced by a

demonstrative determiner (*diese/dieses/dieser* – 'this') to facilitate an anaphoric reading. This latter decision was guided by the following observations. First, corpus data indicate that there is a weak correlation of demonstrative determiners and ontological change indicating that demonstrative complex anaphors (German *diese/dieser/dieses* + N – 'this + N') tend to be more likely to cause ontological change than other forms of complex anaphors (*der/die/das* + N-'the + N') (Consten et al., 2007). Second, demonstratives exclude non-anaphoric or non-deictic readings and are thus preferred in case speakers regard the anaphoric (or deictic) reference as imprecise or difficult to resolve (see Averintseva-Klisch & Consten, 2007). Accordingly, we used demonstrative items in the present study in order to facilitate the participants' acceptance of complex anaphoric readings.

Moreover, context sentences – which always reflected processes – contained predicates and temporal adverbials that emphasised the durativity and atelicity of the described proposition, thereby clearly identifying the utterance as a process. The ontological classification of the context sentence was further double-checked by applying the diagnostics outlined above; felicitous combination with a durative adverbial 'for three minutes/hours/years' served to confirm the durativity feature [+ dynamic] and addition of 'three times' should result in rejection of the utterance, thus substantiating atelicity [-telic].

(19) a. Seit drei Jahren vernichten die Nilbarsche im Viktoriasee nach und nach die meisten Buntbarscharten.
For three years, the Nile perch in Lake Victoria have gradually destroyed most of the cichlid species.
b. #Dreimal vernichten die Nilbarsche im Viktoriasee nach und nach die meisten Buntbarscharten.
#The Nile perch in Lake Victoria have three times gradually destroyed most of the cichlid species.

TABLE 1
Characteristics of complex anaphors

	State anaphor	*Process anaphor*	*Event anaphor*
Mean word frequency class[a]	10.8	11.2	11.2
Mean length per anaphor (in letters)	8.3	9.2	7.8
Mean length per anaphor (in syllables)	2.7	2.8	2.5
Mean general frequency of first syllable (per million)[b]	7562	4321	4748

[a] Based on *Wortschatz Universität Leipzig*. [b] Based on *Celex* database and analysed with the implementation for syllable frequency by Aichert, Marquardt, and Ziegler (unpublished manuscript).

All critical items were evaluated for naturalness and (in)acceptability by five native speakers prior to the start of the investigation. Table 2 provides additional example stimuli.

RATING STUDY

In this section, we present data from a questionnaire study which provides an offline measure of the overall acceptability of the three different anaphoric complexation processes illustrated in Table 2 and (14) above.

Method

Participants. Thirty-six students from the University of Mainz (24 women, 12 men) participated in this questionnaire study. All participants were monolingual native speakers of German. Their ages ranged from 20–31 years (mean age: 24).

TABLE 2
Example stimuli for process/state/event anaphors

(1)	Die Nilbarsche im Viktoriasee vernichten nach und nach die meisten Buntbarscharten. Naturschützer beobachten **diese Entwicklung/dieses Phänomen/*dieses Ereignis** heute mit großer Besorgnis. *The Nile perch in Lake Victoria gradually destroy most of the cichlid species. Conservationists observe **this development/this phenomenon/*this event** nowadays with great apprehension.*
(2)	Der Park in der Innenstadt verwildert langsam aber sicher. Der Stadtrat ignoriert **diesen Vorgang/diesen Zustand/*diesen Unfall** nun schon lange. *The park in the inner city runs to seed slowly but surely. The city council has ignored **this process/this condition/*this disaster** for a long time.*
(3)	Die Zahl der Heroinkonsumenten in Deutschland sinkt kontinuierlich. Vermutlich ist **dieser Prozess/dieser Umstand/*dieses Ereignis** Gegenstand zahlreicher soziologischer Studien. *The number of heroin consumers in Germany decreases continuously. Presumably, **this process/this circumstance/*this event** is a matter of numerous sociological studies.*
(4)	Die Beliebtheit des Ministerpräsidenten schwindet jetzt zusehends. Sicher begeistert **diese Abnahme/diese Situation/*dieses Geschehnis** gerade die Opposition im Parlament. *The popularity of the Prime Minister now diminishes noticeably. Certainly**, this decline/this situation/*this incident** particularly enthuses the opposition in parliament.*
(5)	Der alternde Schriftsteller wurde nach und nach zum Choleriker. Seiner Familie machte **diese Entwicklung/dieses Problem/*diese Begebenheit** außerordentlich zu schaffen. *The ageing writer gradually turned into a choleric person. For his family, **this development/this problem/*this incident** was exceedingly troubling.*

Materials. The acceptability of the items was tested in a paper-and-pencil questionnaire with a 6-point-scale where participants were asked to indicate whether the second sentence represented a felicitous continuation of the first one. Selecting '1' indicated a good fit between the two sentences, while '6' symbolised an infelicitous continuation. Ninety sets were randomly selected from the 120 sets described above and were distributed evenly across six lists of the questionnaire. In each list, the critical items (N = 15 per condition) were interspersed with 15 filler items that were unacceptable, such as nonsense continuations or the use of conceptually awkward anaphors (such as 'The list of extinct plants grows on a daily basis. Environmentalists are increasingly concerned about this #chant.'). Therefore each list contained 60 items.

Data analysis. The mean ratings per condition and participant entered an analysis of variance (ANOVA) with the factor ONTOLOGY (three levels: process, state, event anaphor). Prior to this analysis, the (infelicitous) filler items were used to assess whether participants were paying attention to the material in a sufficient manner. If participants scored below a mean rating of 3 for the filler items, their data were discarded from further analysis. However, none of the participants had to be excluded due to poor responses to the filler items, and the mean ratings of the fillers (mean = 4.86, $SD = 1.51$) revealed an overall good performance on these items.

Results and discussion

The total mean ratings revealed the highest acceptability for PROCESS anaphors (**p←p**) (mean = 2.18, $SD = 0.56$), followed by STATE anaphors (**p←s**) (mean = 2.56, $SD = 0.59$) and EVENT anaphors (**p←*e**) (mean = 3.15, $SE = 0.85$).[2] This contrast was confirmed by an ANOVA with the factor ONTOLOGY, which revealed a main effect of anaphor type, $F_1(2, 70) = 9.03$, $p < .001$; $F_2(2, 178) = 11.48$, $p < .001$. Pairwise comparisons demonstrated a significant effect for the contrast PROCESS vs. EVENT, $F_1(1, 35) = 15.84$, $p < .001$; $F_2(1, 89) = 21.98$, $p < .001$, as well as for the contrast STATE vs. EVENT, $F_1(1, 35) = 6.45$, $p < .02$; $F_2(1, 89) = 10.35$, $p < .002$. The comparison between the two anaphors that conformed to the

[2] It is somewhat surprising that the average ratings for the critical conditions are not more spread out along the 6-point scale. However, the common rating behaviour of the participants indicates that they were generally reluctant to assign extreme ratings. This is also indicated by a mean rating of 4.86 for the infelicitous items. This tendency might have to do with the complexity of the stimulus material and the subtleness of the ontological manipulation. Nonetheless, statistical analyses indicate a clear divergence for the event anaphors.

abstractness constraint revealed no significant differences: PROCESS vs. STATE, all Fs < 2).

The nominal measures from the rating study suggest that maintaining the same ontological type is the most preferred anaphoric mechanism during complexation processes, while shifting the ontological type is less preferred. The finding that event anaphors with process antecedents obtain the worst rating furthermore supports the abstractness constraint and the claim that reconstruction of ontological features is not possible during anaphoric resolution. In addition, the fact that state anaphors that refer to a previously introduced process are rated somewhat less acceptable than process anaphors indicates that participants were aware of the reduction of ontological categories in a conscious task like the judgement task employed here. Nevertheless, the responses to process and state anaphors – which both adhere to the abstractness constraint – do not differ reliably from one another, providing support for the claim that feature reduction is a possible means during the resolution of complex anaphors. Overall, the findings from the rating study thus confirm the claims derived from the abstractness constraint that feature reduction is allowed by the language system, but feature reconstruction is not. The data further substantiate previous findings from corpus analysis.[3]

ERP STUDY

Utilising ERP measures, we also obtained online measures of anaphoric complexation processes in order to shed light on the real-time properties of anaphoric complexation.

[3] We carried out the same rating study with the participants from the ERP study reported in this paper (N = 24), who were asked to complete the questionnaire following the ERP recording. The general pattern described above was confirmed by this study with a main effect of ONTOLOGY, $F_1(2, 36) = 6.82$, $p < .003$; $F_2(2, 178) = 8.37$, $p < .001$, and for the (more meaningful) items analysis, reliable differences between both process and state anaphors vs. event anaphors, as well as no significant differences between process and state anaphors. Yet, the analysis by subject yielded slightly different results, with significant differences between process vs. event and process vs. state, and only a marginal difference ($p < .09$) for state vs. event. However, two caveats led us to carry out an independent study (as suggested by anonymous reviewers). First, data from five participants had to be discarded from further analysis because their average ratings of the (unacceptable) filler items were lower than 3, indicating that these participants were not paying attention in a satisfactory manner. Second, the overall rating behaviour indicated a bias toward the acceptable end of the scale (with mean ratings of 1.81 for process anaphors, 2.17 for state anaphors, 2.58 for event anaphors, and 4.81 for the incorrect filler items). This could be due to prior exposure of the critical constructions leading to biased rating behaviour or it could be caused by the participants' weariness following the ERP session.

Method

Participants. Twenty-four students (12 women, 12 men) from the University of Marburg participated in this study. All participants were monolingual native speakers of German, right-handed (assessed by a German version of the Edinburgh handedness test) and reported normal or corrected-to-normal visual acuity. Their ages ranged from 21–28 years (mean age: 24). Two participants had to be discarded from the analyses of the ERP data due to excessive ocular artifacts.

Materials. As outlined above, 120 sets with three conditions each were constructed for this investigation. The resulting 360 items were assigned to three lists of 120 items each. Participants were hence presented with 40 items per condition (process anaphor, state anaphor, event anaphor). In addition, 40 filler items were constructed that also consisted of a context and a target sentence, but that did not contain a complex anaphor. This yielded a total of 160 items per list, which were presented in four blocks of 40 items each and were pseudo-randomised so that each block started with at least one filler item and a given condition would not be repeated more than once in the order of items. Furthermore, participants had to perform a word recognition task after each context-target sentence pair. To this end, each item was matched with a correct and an incorrect lexical item and the presentation of these was counter-balanced across participants.

Procedure and data analysis. Participants were seated in a dimly lit and sound-attenuating booth. They were instructed to read the material for comprehension and to respond to a word recognition task after each stimulus item. Stimuli were presented visually in the centre of a computer screen in yellow letters against a blue background. They were presented in a segmented manner (i.e., word- or phrase-wise) with a fixed presentation rate of 600 ms per segment and an inter-stimulus interval (ISI) of 150 ms. Each trial began with the presentation of three adjacent asterisks (300 ms plus 200 ms ISI) to focus the participants' attention to the centre of the computer screen and ended with a blank screen of 750 ms, after which participants were required to complete the word recognition task by pressing a 'yes'- or 'no' -button on a response box. Response hands were counter-balanced across participants. Following the button-press, there was an intertrial interval of 1000 ms before the presentation of the next item. Participants were asked to avoid movements and to only blink their eyes between their response to the word recognition task and the presentation of the next stimulus.

After participants were prepared for the experiment, a short training session was carried out, followed by four experimental blocks, between which participants took short breaks. Finally, participants were asked to

fill out a questionnaire that assessed the acceptability of the critical material (see section 'Rating Study', footnote (3) for further details). The entire experiment (including electrode preparation) lasted approximately 2 hours.

The electroencephalogram (EEG) was recorded from 24 Ag/AgCl electrodes fixed at the scalp by means of an elastic cap (*EasyCap*), with the ground electrode placed at C2. Recordings were referenced to the left mastoid, but rereferenced to linked mastoids offline. The electrooculogram (EOG) was monitored by electrodes placed above and below the participant's left eye and at the outer cantus of each eye (to monitor eye movements). Electrode impedances were kept below 5 kΩ. All EEG and EOG channels were amplified using a *BrainVision Brain-Amp* amplifier and recorded with a digitisation rate of 250 Hz.

The ERP analyses are based on trials that registered a correct answer to the word recognition task and contained no ocular or muscular artifacts. These criteria amounted to the exclusion of 19.99% of the data points (6.95% due to incorrect or time-out responses in the recognition task and 13.05% from artifacts – this is a normal exclusion rate for EEG recordings, which is anticipated and countered by the high number of items per condition). Average ERPs were time-locked to the onset of the complex anaphor (*this development* in (14a)) and calculated per condition and participant, before grand-averages were computed over all participants. Repeated-measures analyses of variance (ANOVAs) were performed with the factor ONTOLOGY (three levels: process, state, event anaphor) for lateral and midline electrodes separately. The lateral analyses included the factor region of interest (ROI) (with four levels: left anterior (F3/F7/FT7/FC5), right anterior (F4/F8/FT8/FC6), left posterior (C3/CP5/P3/P7), right posterior (C4/CP6/P4/P8)) and the midline analysis included the factor ELECtrode (with five electrodes as separate levels: Fz, FCz, Cz, CPz, Pz). All analyses were carried out in a hierarchical manner on the mean amplitude value per condition, i.e., only significant interactions ($p < .05$) were resolved. To avoid excessive type 1 errors from violations of sphericity, we applied the correction of Huynh and Feldt (1970) when the analysis involved factors with more than one degree of freedom in the numerator. Time windows were chosen on the basis of previous investigations and visual inspection of the data, and we report mean amplitude values for the window between 420 and 580 ms below.

For the behavioural data, error rates as well as reaction times were calculated for each condition. Incorrectly answered trials were excluded from the reaction time analysis. An ANOVA involving the factor ONTOLOGY was carried out with the random factors subjects (F_1) and items (F_2).

Results and discussion

The ANOVA of the responses to the word recognition task showed that participants were performing at ceiling level (92% correct on average) and revealed no significant effects both by error rates and by reaction times (Fs < 1).

Figure 2 shows grand average ERPs at the position of the complex anaphor for process, state, and event anaphors. It demonstrates that event anaphors elicit a more pronounced negativity in the time range from 420–580 ms in contrast to process and state anaphors, indicating that the violation of the abstractness constraint is detected within this temporal

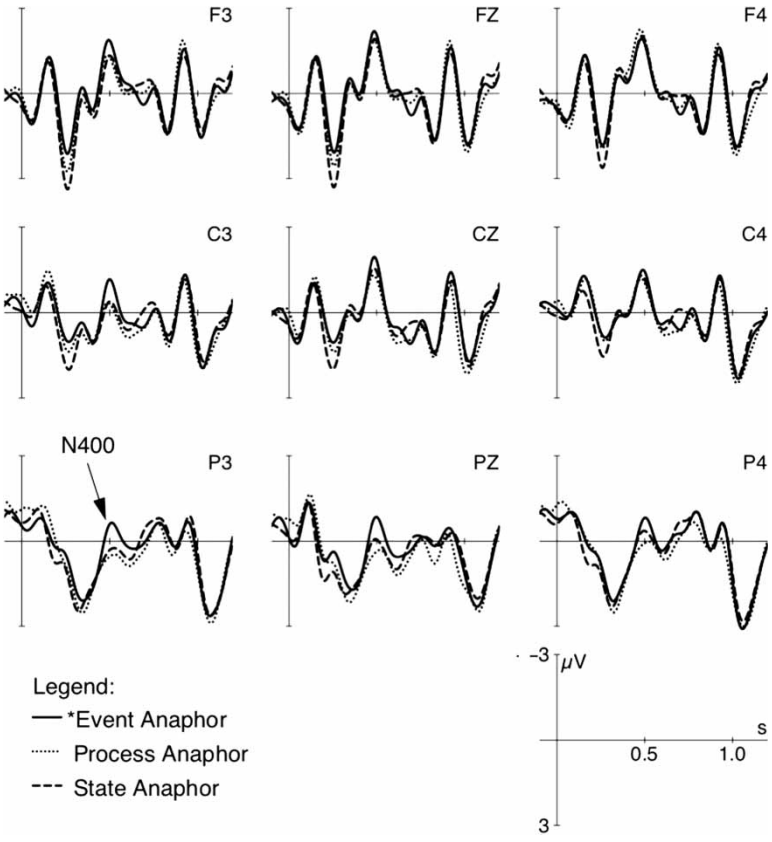

Figure 2. Grand average ERPs recorded to the onset of the critical anaphor (onset at vertical bar) at nine selected electrode positions. Event anaphors (solid line) show an enhanced negativity for the violation of the abstractness constraint relative to Process anaphors (dotted line) and State anaphors (dashed line). Time-course is plotted on horizontal axis (-0.1–1.2 s); voltage fluctuations are plotted on vertical axis with negative voltage going upwards.

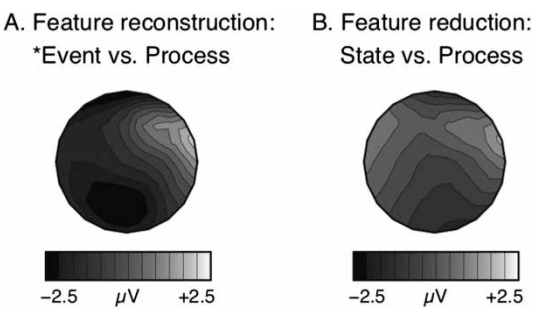

Figure 3. The topographical distribution of the observed negativity for the time window between 420 to 580 ms shows more activation over left-lateralised regions for event anaphors (A). The voltage differences between state and process anaphors in the same time window were not significant (B). Frontal electrodes are at the top of the maps.

window. This was confirmed by statistical analyses. In the analysis over lateral electrode regions, the ANOVA revealed an interaction of ONTOLOGY × ROI, $F(6, 126) = 5.16$, $p < .001$, which was resolved in the left anterior ROI, $F(2, 42) = 5.16$, $p < .01$, and the left posterior ROI, $F(2, 42) = 3.74$, $p < .05$. Pairwise comparisons in these ROIs revealed main effects of ONTOLOGY for the contrast EVENT vs. PROCESS, left anterior ROI: $F(1, 21) = 4.38$, $p < .05$ and left posterior ROI: $F(1, 21) = 7.90$, $p < .02$, and EVENT vs. STATE, left anterior ROI: $F(1, 21) = 8.80$, $p < .01$ and left posterior ROI: $F(1, 21) = 5.13$, $p < .05$, but no effects for PROCESS vs. STATE (all Fs < 1.1). The analysis of the midline electrodes yielded no significant effects (Fs < 2). Figure 3 illustrates the topographical distribution of the negativity for the paired comparisons reflecting feature reconstruction and feature reduction.

The ERP data provide novel evidence for the mechanisms underlying anaphoric complexation. They reveal that violations of the abstractness constraint – here, changing the ontological type by referring to a process with a less abstract event anaphor – result in an enhanced negativity. The negativity has the typical features of the N400 as far as latency is concerned, with a left lateralised centre (as illustrated by the topographical maps in Figure 3). From a functional perspective, the findings complement previous research on the referential nature of the N400 and show that ontological features are activated automatically and early in the course of complex anaphor resolution and that processing demands are exerted by a false direction of the implicational relation between antecedent and anaphor. This indicates that an abstract entity in discourse representation carries specific ontological features and cannot be reanalysed towards a less abstract entity, i.e., its ontological category must be maintained or referred to in more abstract terms (i.e., undergo feature reduction).

In fact, shifting to a more abstract ontological type does not exert additional processing demands as evidenced by the absence of different electrophysiological patterns for process and state anaphors. This suggests that ontological categories are implicationally related in such a way that more abstract representations can be activated at no further expense. This also confirms the predictions made by the abstractness constraint.

Figure 2 also indicates a more pronounced early positivity, possibly a P200, for state anaphors. This was confirmed by statistical analysis in the time window from 150–300 ms with a main effect of ONTOLOGY over lateral ROIs, $F(2, 42) = 6.98$, $p < .01$, as well as over midline sites, $F(2, 42) = 5.99$, $p < .01$. Paired comparisons registered reliable differences for STATE vs. PROCESS, lateral: $F(1, 21) = 8.81$, $p < .01$; midline: $F(1, 21) = 7.20$, $p < .02$, and STATE vs. EVENT, lateral: $F(1, 21) = 22.76$, $p < .001$; midline: $F(1, 21) = 19.20$, $p < .001$, and no significant effect for PROCESS vs. EVENT (Fs < 1). P200 effects have previously been reported for physical features associated with the input as well as other intrinsic factors. We return to a discussion of these issues in the General discussion.

GENERAL DISCUSSION

The present study was designed to assess reference resolution of complex anaphors, and the electrophysiological data confirm the abstractness constraint that prohibits complex anaphoric reference that evokes a shift of the referent to a less abstract ontological category. The validity of the abstractness constraint is reflected in an enhanced negativity to event anaphors that pick up a previously introduced process (which is a more abstract category).

In the theoretical model described by Consten and Knees (2008), it was proposed that the abstractness constraint as part of the reader's general knowledge base – which contains lexical and conceptual knowledge – comes into play in the phase of resolving the complex anaphor, i.e., when one of several prementioned referential structures is reactivated and identified as the most appropriate one within the ongoing mental text world (i.e., discourse representation). In case none of the prementioned referential structures persist this ontological check, an N400 effect occurs as the result of the failing resolution process. This indicates again that activation of ontological features and referential processing are closely connected, but the model outlined in Consten and Knees (2008) also proposes that the abstractness constraint affects anaphor resolution, which fits best with the integration view of the N400. Moreover, as indicated in the materials section, all complex anaphors were introduced by a demonstrative determiner, which provides additional support for the integration over the lexical preactivation view, since

demonstrative determiners make the anaphoric reading more easily available, in fact they force an anaphoric or deictic reading.

In contrast to shifting the ontological type to a less abstract category, identity relations (referring to a process by a process anaphor) and the use of anaphors referring to more abstract ontological types (referring to a process by means of a state anaphor) are equally licensed during online reference resolution. This follows from the featural setup of the respective referential expressions. Accordingly, a shift to a more abstract category implies a reduction of referential features. Reduction is always possible, whereas reconstruction of such features is not. The ERP data reveal that reduction of ontological features towards a more abstract type does not elicit an enhanced negativity. Thus, abstraction exerts no extra processing demands during online integration. This indicates that different ontological types are implicationally related in such a way that more abstract representations can be activated at no further expense (but see also the discussion of the P200 effect further below). It also shows that feature reduction takes place automatically in online processing.

As pointed out above, the observed N400 in the present experiment shows a left-lateralised maximum (see Figure 3), which diverges somewhat from the broad centroparietal distribution that is typically reported for the N400. However, while ERPs do not present a good basis for localisation claims, the particular distribution observed in our study might indicate that different activation or integration processes underlie the N400 signature. In this regard, investigations of the contribution of the right and left cerebral hemispheres to language processing have suggested that processes associated with more coarse-grained semantic information are subserved by the right hemisphere, while more focused activation and finer grained processing is subserved by the left hemisphere (cf. e.g., Jung-Beeman, 2005 for an overview). To illustrate this, research on lexical ambiguity utilising visual hemifield presentation suggests for instance that left hemisphere processes focus on features related to the contextually dominant meaning, while the right hemisphere activates all possible meanings (e.g., Chiarello, Liu, Shears, Quan, & Kacinik, 2003; Meyer & Federmeier, 2007).

In a follow-up to the within/between category manipulation illustrated in example (10) above [*They wanted to make the hotel look more like a tropical resort. So along the driveway, they planted rows of palms/pines/tulips.*], Federmeier and Kutas (1999b) combined ERP recordings and visual hemifield presentation and showed that the category membership was modulated by N400-differences evoked by the left hemisphere, but not by the right hemisphere. These findings indicate that left hemisphere processes are guided by the activation of features of expected upcoming information, while right hemisphere processes reflect broader integration processes. The left hemisphere thus seems to operate on a finer grained level and is more

predictive in that it restricts feature activation; the right hemisphere in turn activates a less restricted candidate set and is sensitive to looser semantic associations. The observed left-lateralised N400-differences might thus be reflective of anticipatory activation of ontological features – possibly triggered by the presence of the demonstrative determiner or general discourse coherence principles – which are not met when a complex anaphor is encountered that denotes an event. In case the respective neural generators could also be localised in the left hemisphere – which on the basis of the ERP data is a mere speculation – this would indicate that specific abstract features that are associated with a lexical-semantic representation are represented in this region. However, this view should be followed up by research employing methodologies that are more eligible to make localisation claims.

In addition, the ERP data also revealed a pattern specific to state anaphors: a more pronounced P200. The P200 has previously been shown to be sensitive to physical features, such as length, frequency, position, or acoustic properties of the input (cf. e.g., Barber, Vergara, & Carreiras, 2004; Dambacher, Kliegl, Hofmann, & Jacobs, 2006; Heim & Alter, 2006; Woldorff & Hillyard, 1991). Length and word frequency cannot account for this early difference, since critical anaphors were controlled for these parameters (see Table 1 for mean values per anaphor type). Barber et al. (2004) reported syllable frequency effects as early as in the P200-window. We therefore calculated the frequencies for the first syllables of our critical stimuli (see Table 1). State anaphors yielded the highest frequency (7562 occurrences per million) and differed significantly from event anaphors (4748 occurrences per million) and process anaphors (4321 occurrences per million) ($ps < .001$). Yet, these contrasts do not converge with previous reports on syllable frequency effects that registered most pronounced P200 amplitudes for low frequency items. Accordingly, physical features of the input are not likely to account for the observed P200 effect. Rather, it appears to be more promising to attribute the difference to the lexical-semantic feature setup. In this regard, Malaia, Wilbur, and Weber-Fox (2009) reported P200 modulations as a function of telicity. In the present study, telicity cannot account for the observed difference (because states pattern with processes in being atelic), but durativity [$\pm$ dynamic] separates states on the one hand from processes and events on the other hand. The feature [-dynamic] does not seem to be expected, and the positivity thus marks early lexical access and suggests that intrinsic features such as durativity and telicity are processed. Alternatively, it could be argued that the positivity represents a first indication of feature reduction and recomputation of ontological features. This would then suggest that feature reduction is costly after all. However, given its early onset latency, we do not take this P200 to be a reflex of anaphoric integration, but rather of lexical-semantic access.

In general, the ERP data substantiate earlier findings from corpus counts that reported no instances of violations of the abstractness constraint (Consten et al., 2007). In addition, the corpus study revealed that the majority of the observed ontological category changes targeted abstract objects in the terms of Asher (1993) (i.e., facts and propositions). Our data extend these findings to situational categories. Following from this, two issues are left to discussion concerning anaphoric complexation and the stimulus items used in the present investigation.

First, in the present investigation, we used simplified items matching ontological changes within situational categories (events, processes, states) and not abstract objects in Asher's (1993) notion (facts and propositions). Thus, our items do not reflect the full range of informational functions that complex anaphors can fulfil. Nonetheless, by focusing on situational anaphors, we take advantage of dealing with ontological types on a clear-cut hierarchical ranking. This would have been doubtful with the so-called abstract objects: in Consten, Knees, and Schwarz-Friesel (2009), it is argued that 'being a fact vs. proposition' is not really an ontological property such as 'being an event'. The process referent of a sentence like *The Nile perch in Lake Victoria gradually destroy most of the cichlid species.* (repeated from (14) above) remains a process referent when it is picked up by an abstract object anaphor like *this fact, this lie*, or *this claim*. In these cases, the anaphor rather provides an additional truth value feature arising from epistemic marking.

Second, in natural language data, the cotext has an essential impact on complexation processes. Consten and Knees (2008) illustrate how the argument structure of the verbs embedding a complex anaphor differentially influence anaphoric complexation. Consider the following examples:

(20) *Michael fought against the dragon.* ***This battle*** *lasted for the whole day.*
(21) *Michael fought against the dragon.* ***This battle*** *proves that Michael was inspired by the Holy Ghost.*

Due to the cotextual embedding, the process referent of the antecedent can be picked up as a process (see (20)). In contrast, since a process can only serve as a proof if it is factual, the referent gets a factual reading in (21). In analogy to this, one might want to discuss whether a verb like *observe* (in (14)) facilitates a factual reading, since only real processes can be observed. However, this does not have a bearing on the present investigation, since we did not test fact/proposition categories and because we avoided verbs that support certain situational types like *last* (process) and *happen* (event). Moreover, a particular cotext occurred in all three conditions.

We therefore conclude that the abstractness constraint can not only be deduced from theoretical definitions of ontological types but was also

confirmed by online processing data, reflected in a more pronounced negative ERP deflection, as well as by questionnaire data, the latter reflecting more conscious decisions. The findings thus indicate that ontological features are encoded in the mental representations that are involved in referential processing. We interpret the negativity with respect to anaphoric integration on the basis of both the theoretical model of complexation processes and the fact that more abstract anaphors elicited an additional earlier positivity, which we attribute to lexical-semantic processing. A second issue investigated in this paper was whether ontological change – irrespective of its direction – evokes additional processing costs in the course of the anaphoric resolution process. Given our interpretation of the N400, the absence of this effect for state anaphors indicates that this is not the case: in online processing, ontological shifts are only costly when the abstractness constraint is violated (hence automatically blocking feature reconstruction). In cases where shifts result in ontological feature reduction, no additional integration costs accrue. Interestingly, the featural differences emerging in the latter case are reflected in earlier processing stages. These findings have implications for our understanding of the representation and processing of ontological features in reflecting the involvement of distinct neural networks and providing empirical support for entailment relations.

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