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ORIGINAL ARTICLE

The processing difference between person names and common nouns in sentence contexts: an ERP study

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Abstract Person names and common nouns differ in how they are stored in the mental lexicon. Using event-related potentials, this study compared the integration of names and nouns into sentence contexts. Both person names and common nouns were highly related in meaning and either congruent or incongruent within the previous contexts. Name incongruence elicited an N400 effect, suggesting that people were able to rapidly retrieve the semantic meaning of names from long-term memory even when this process was mediated by person identification. Conversely, participants showed a "good enough" processing of the nouns due to their low specificity level and, thus, rich semantic associations, leading to a P600 effect. These distinctive ERP effects provide clear evidence for the distinctive semantic representations of these word categories by showing that the activation of a name's meaning is mediated by a single connection between identity-specific information and person identity, whereas multiple connections exist between nouns and their meanings.

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Introduction

Both person names (e.g., "Thomas Edison") and common nouns (e.g., "inventor") can be used to refer to individuals. However, they differ greatly in their level of specificity as person names generally refer to specific individuals (e.g., "Thomas Edison" refers to the inventor who invented the light bulb), while common nouns represent a group of individuals with similar characteristics (e.g., an "inventor" can be anyone who creates novel things). Moreover, person names themselves convey little or no information about the name bearers unless the represented individuals are identified (Kripke, 1981); therefore, the semantic meaning of names is determined by the associated information of the name bearers (Frege, 1979; Russell, Ward & Pratt, 1981; Sciarone, 1967). In contrast, common nouns contain intrinsic meaning and imply specific attributes as the meaning of nouns has been internalized after being repeatedly associated with certain type of referents, so the retrieval of nouns' meaning does not rely on the identification of a specific referent.

Previous empirical studies employed a variety of tasks to study the processing differences between person names and common nouns. For instance, when asked to decide whether a word was a name or a noun, people were faster at identifying names compared to nouns (Müller, 2010; Yen, 2006). Similarly, when asked to judge the relatedness of two names or nouns, people were faster at recognizing the association of names (e.g., "Woody" and "Allen") than that of nouns (e.g., "social" and "security") even when the frequency between the names' and nouns' associations was matched (Proverbio, Mariani, Zani & Adorni, 2009). In both the categorical decision and semantic association tasks, the meaning carried by the names was not necessarily activated. However, in a phonological retrieval task, in which the participants were asked to retrieve the names or nouns based on definitions of the words, the retrieval of names was slower than that of nouns (Proverbio, Lilli, Semenza & Zani, 2001). Similarly, people made slower judgments regarding the emotional valence of names (e.g., to judge "Hitler" as negative) than that of nouns (e.g., to judge "gun" as negative) (Wang, Zhu, Bastiaansen, Hagoort & Yang, 2013). Overall, comparing to nouns, although the recognition of names seems to be easier, the retrieval of the *meaning* of names seems to be more challenging. Furthermore, neuropsychological studies found that neurological damage can cause selective impairments in the recognition or retrieval of names or nouns (for reviews see Semenza, 2006, 2009, 2011).

The processing differences between names and nouns can be accounted for by a name-processing model proposed by Valentine, Moore and Brédart, (1995). This model is concerned with the processing of isolated words. In this model, name processing involves several stages: word recognition, name recognition, person identification (i.e., a psychological process to link the name to the individual), and finally, the activation of associated information (i.e., the characteristics of the name bearer). Since recognition and retrieval of names relate to different stages within name processing (i.e., name recognition and activation of associated information, respectively), the processing of names and nouns show different patterns. The model further implies that there is only a single connection between a name and its referential meaning (via person identification); whereas, multiple connections exist during the retrieval of a noun's meaning. For instance, the name "Thomas Edison" is connected to its semantic information (e.g., an American inventor) only via the known individual called "Thomas Edison". Nevertheless, the noun "inventor" is connected to a large number of associations representing semantic information about inventors, such as "those who produce something by using ingenuity or imagination". This assumption has obtained empirical support from neuropsychological and neuroimaging studies. It has been shown that the left anterior temporal lobe serves as a hub, binding semantic attributes of unique entities, such as those labeled by person names (Drane et al., 2008; Grabowski, Damasio, Tranel, Ponto, Hichwa & Damasio, 2001; Tranel, 2009). The temporal pole, thus, works in connection with a wider network (such as prefrontal and medial frontal areas) to support the processing of names (Grabowski et al., 2001; Yamadori et al., 2002; Yen, 2006).

Although some processing differences between names and nouns have been studied previously, relatively few studies exist regarding how person names are integrated into a sentence-level context (i.e., how to combine the meaning of a person name with other elements of a sentence). It has been well established that context can facilitate the lexical retrieval of words and that people immediately integrate all available information into the context (van den Brink et al., 2011; Wang, Hagoort & Yang, 2009). Various neurobiological models have attempted to explain how the brain derives meaning from linguistic input (Bornkessel-Schlesewsky & Schlesewsky 2013; Brouwer & Hoeks, 2013; Friederici, 2011; Hagoort, 2013; Hickok & Poeppel, 2007). These models differ in the spatial and temporal characteristics of particular processes involved in language comprehension (such as memory retrieval, syntactic parsing and combinatory processing), but it is generally believed that the retrieval of words' meaning occurs at temporal regions, and that the meaning of individual words can be available around 200 ms after the words' onset. However, these models were mainly built on studies of words that refer to a class of referents (such as common nouns) or properties (such as adjectives and verbs). As mentioned earlier, nouns and names differ in their levels of specificity. Also, the retrieval of names' meaning involved different brain regions compared to that of nouns (for a review see Semenza, 2011). Therefore, it is essential to study how person names are integrated into a sentence context to gain a full understanding of the neural mechanisms underlying language comprehension.

One particularly useful way to study language processing is by measuring event-related potentials (ERPs). ERPs have a high temporal resolution and do not require additional tasks (such as semantic or grammatical judgment) except to comprehend language input (Luck, 2005). In addition, specific ERP components can be associated with particular cognitive processes. Two well-known ERP components have been associated with language processing. First, the N400: this is a negativity that peaks around 400 ms after stimulus onset, with a typically centro-parietal maximum distribution (Kutas & Hillyard, 1980). The N400 amplitude varies as a function of how easily a word is integrated into (or pre-activated by) the previous context. Specifically, semantically unexpected words elicit a larger N400 than semantically compatible words. The N400 difference has been classified as the N400 effect (Hagoort, Hald, Bastiaansen & Petersson, 2004). In addition to expectation violation, the N400 effect has also been shown to be sensitive to complement coercion (Kuperberg, Choi, Cohn, Paczynski & Jackendoff, 2010; Baggio, Choma, van Lambalgen & Hagoort, 2010). For instance, in sentence "The journalist began/wrote the article before his coffee break", the coerced noun ("article" following "began") evoked an N400 effect relative to non-coerced complement noun ("article" following "wrote"). Second, the P600: this is a positivity that occurs roughly between 500 and 1,200 ms post-stimulus, with a centro-posterior distribution. The P600 effect is typically found in response to syntactic violations (Hagoort, Brown & Groothusen, 1993; Osterhout & Holcomb, 1992) as well as syntactic ambiguities (Frisch, Schlesewsky, Saddy & Alpermann, 2002) and complexity (Kaan, Harris, Gibson & Holcomb, 2000), but is also elicited by meaning-related violations (Kuperberg, 2007; Nieuwland & Van Berkum, 2005; Sanford, Leuthold, Bohan & Sanford, 2011; Van Petten & Luka, 2012). For instance, some studies observed a P600 effect in addition to an N400 effect (Van Petten & Luka, 2012). In addition, a series of studies have reported a P600 effect instead of an N400 effect for semantic verb–argument violations (e.g., "The egg eats/is eaten for breakfast"; Kuperberg, 2007). It should be noted, however, that since the argument structure violation is part of syntax–semantic interface, the observed P600 effect in response to argument structure violations might also be a consequence of syntactic analysis. Moreover, a P600 effect, instead of an N400 effect, was found when the violating information fitted the global context but not the local context (e.g., "Child abuse cases are being reported much more frequently these days. In a recent trial, a 10-year sentence/care order was given to the victim, but this was subsequently appealed."; Nieuwland & Van Berkum, 2005; Sanford et al., 2011). Therefore, the P600 effect might reflect prolonged analysis of unexpected input in general (Kuperberg, 2007; Van Petten & Luka, 2012). It should be noted that the semantic P600 effect is subject to cross-linguistic variation (Bornkessel-Schlesewsky et al., 2011; Tune et al., 2014) and that good-fit anomalies could also elicit a reduced but reliable N400 effect compared to poor-fit anomalies (Bohan, Leuthold, Hijikata & Sanford, 2012). Thus, the N400 and P600 occur independently.

The above-mentioned ERP results were primarily obtained in studies of common nouns, verbs or adjectives. Given the numerous distinctions between person names and common nouns, it is essential to examine how person names are processed in context. A recent ERP study investigated how people integrate novel meanings for previously unknown person names into a discourse context (Wang & Yang, 2013). In this study, the meaning of person names was formed by first presenting two-sentence descriptions of the names (e.g., "Xiaojin and Xiaochang are both very famous. Xiaojin is a singer, whereas Xiaochang is an actor."). Subsequently, in target sentences, the meaning of person names either matched or mismatched the previously established context (e.g., "Yesterday, a film producer/a music producer came to Xiaochang for collaboration."). The participants were asked to judge the congruence of every discourse. Incongruent names elicited a larger N400 as well as a larger P600 than the congruent names, indicating that the established meaning could be rapidly retrieved and integrated into the context. However, since the meaning of names was obtained from the discourse context, the meaning might still have been available in working memory when processing the target sentence. Consequently, the discourse incongruence might have been immediately detected which resulted in the N400 effect. Unlike novel names, the meaning of famous names has to be retrieved from long-term memory, which involves several stages, such as: word recognition, name recognition, person identification and activation of associated information (see Valentine et al., 1995). Presently, it remains unclear how famous names are retrieved and integrated into sentence context. Moreover, as the previous study (Wang & Yang, 2013) only examined the ERP responses to incongruent names, the present study will directly compare the ERP responses to the processing of names and nouns using a fully within-subject design by presenting them in the same sentence contexts.

The present study examines how famous person names and common nouns are processed in sentences. To directly compare the processing of person names and common nouns, we used nouns that were closely related to the person names, such as "inventor" and "Edison". We manipulated the congruence of person names and common nouns in sentences. Each sentence contained two clauses. The first clause set-up a particular context (e.g., "In terms of influences on human science/the progress of literature and art, …") and the second clause contained a critical name or noun that was either congruent or incongruent relative to the context (e.g., "… everyone acknowledged Edison's/the inventor's contribution."). Note that the incongruence can only be detected if the critical name or noun is linked to the first clause of the sentence. ERP effects elicited by the incongruence (i.e., the difference waveforms between the incongruent and congruent conditions) will be compared between names and nouns. Given the limitation of spatial resolution of ERPs, we will only make predictions regarding the time course of information processing. The time latency of the N400 effect was shown to be quite constant across studies using different stimuli (such as words, pictures and sounds; see Kutas and Federmeier, 2011 for a review), indicating that semantic analysis/integration occurs in this relatively fixed time window. Therefore, based on previous studies that employed easy-to-detect incongruence sentences (Kutas & Hillyard, 1980; Wang & Yang, 2013), an N400 (and possibly a subsequent P600 effect) will be elicited if people can rapidly retrieve the meaning of the words. However, no N400 effect will be observed if the meaning retrieval is delayed. In other words, the presence or the absence of an N400 effect in response to the semantic violations will allow us to test the time course of semantic processing of names and nouns in sentence contexts. Specifically, as the meaning of common nouns can be retrieved immediately after word recognition (Dien, 2009), an N400 effect should emerge for the violation of nouns. Since previous studies occasionally reported a P600 effect in addition to an N400 effect (Van Petten & Luka, 2012), the N400 effect might be followed by a P600 effect. Conversely for names, as the connection between a name and its referential meaning occurs via person identification (e.g., Valentine et al., 1995), the meaning retrieval of person names might be relatively delayed compared to that of common nouns (leading to a P600 effect in response to the violation of names). However, if the meaning of names can still be rapidly retrieved by the support of the contextual information; then, an N400 effect will be observed. We will also directly compare the ERPs elicited by the names and nouns. We expect that the names will elicit a larger P600 than the nouns if prolonged analysis of names is involved.

Materials and methods

Ethics statement

The study was approved by the Institutional Review Board of the Institute of Psychology, Chinese Academy of Sciences. All participants provided written, informed consent before taking part in our experiment.

Participants

Twenty-four university students (mean age 22 years, 18–25 years old; 8 males) participated as paid volunteers. They were all right-handed native Mandarin Chinese speakers with normal or corrected-to-normal vision. None of them reported reading difficulties or neurological impairments. The data of two female participants were excluded from further analysis due to either extensive alpha waves or slow drift of the signal. The final set of participants therefore consisted of 22 participants (mean age 22 years, range 19–25; 8 males).

Stimuli

We collected 94 famous person names as well as 94 corresponding nouns from Chinese web pages based on the co-occurrence of the names and nouns in queries, such as “周恩来 (Zhou Enlai)” and “外交家 (diplomat)”, “爱迪生 (Edison)” and “发明家 (inventor)”. The names included both Chinese names that consisted of first and last names as well as transcribed foreign names. Twenty raters (different from the EEG participants; mean age: 22 years old, range 18–25; 4 males) rated the familiarity, imageability, emotional valence and arousal of both names and nouns, as well as the relatedness between names and nouns on 7-point Likert scales (seven indicates the most familiar, imaginable, positive, arousing, and related).

Word selection

We intended to select names that are familiar to the participants and pairs of names and nouns that are high in relatedness. Therefore, we first selected the names whose familiarity scores exceeded 3.5. Then we selected the name and noun pairs whose relatedness scores were larger than 4.1. Finally, 88 name and noun pairs were selected. Statistical analyses comparing the names and nouns showed that the names were more familiar (Mean ± SD = 5.55 ± 0.71 vs. 5.05 ± 0.81; $F_{(1,19)} = 15.88$, $p = 0.001$), more imaginable (Mean ± SD = 5.16 ± 0.86 vs. 4.71 ± 0.78; $F_{(1,19)} = 16.68$, $p = .001$), more positive (Mean ± SD = 4.67 ± 0.69 vs. 4.48 ± 0.52; $F_{(1,19)} = 9.95$, $p = 0.005$) and more arousing (Mean ± SD = 4.41 ± 1.19 vs. 4.05 ± 1.02; $F_{(1,19)} = 14.77$, $p = 0.001$) than the nouns. The relatedness between the names and nouns was very high (Mean ± SD = 6.13 ± 0.60). The names and nouns were matched for the number of strokes: Mean ± SD = 22.35 ± 6.81 and 21.94 ± 7.60, respectively; $F_{(1,174)} = 0.14$, $p = 0.71$. The selected personal names varied in occupation (i.e., politician, entertainment, fictional or scholar), sex (male or female) and popularity epoch (past, recent or current).

Sentence construction

Based on the 88 name and noun pairs, sentences were created such that the names and nouns (hereafter defined as critical words or CWs) were either congruent or incongruent with the sentence context (See Table 1 for examples). All sentences contained two clauses with the first clause being the lead-in clause, while the second clause was the main clause. The CWs were always placed in the second (main) clause, which was either congruent or incongruent with the information provided in the first clause. The number of words in the sentences ranged between 7 and 15 and there was always at least one word before and after the CWs in the second clause. Overall, two factors were independently manipulated: Category (Name, Noun) and Congruence (Congruent, Incongruent), which created four conditions: Name-Congruent (Name-C), Name-Incongruent (Name-IC), Noun-Congruent (Noun-C) and Noun-Incongruent (Noun-IC). See supplementary materials for more examples. Note that it is not mandatory to place a specific article (i.e., “the” or “an/a”) in front of a noun to indicate the status of the noun in mandarin Chinese, so the noun (e.g., “inventor”) was not necessarily specified anywhere in the context.

Table 1 Examples of two experimental items

Example 1:

Name-Congruent:

为了使中国在**国际舞台上**具有更大的影响力，大家都认为周恩来做出了巨大努力。

(In order to make China on an **international stage** exert a larger influence, everyone agrees Zhou Enlai made a great effort.)

(In order to have China exert a larger influence on an **international stage**, everyone agrees that Zhou Enlai made a great effort.)

Noun-Congruent:

为了使中国在**国际舞台上**具有更大的影响力，大家都认为外交家做出了巨大努力。

(In order to make China on an **international stage** exert a larger influence, everyone agrees diplomat made a great effort.)

(In order to have China exert a larger influence on an **international stage**, everyone agrees that the diplomat made a great effort.)

Name-Incongruent:

为了使中国在**美国好莱坞**具有更大的影响力，大家都认为周恩来做出了巨大努力。

(In order to make China in **American Hollywood** exert a larger influence, everyone agrees Zhou Enlai made a great effort.)

(In order to have China exert a larger influence in **American Hollywood**, everyone agrees that Zhou Enlai made a great effort.)

Noun-Incongruent:

为了使中国在**美国好莱坞**具有更大的影响力，大家都认为外交家做出了巨大努力。

(In order to make China in **American Hollywood** exert a larger influence, everyone agrees diplomat made a great effort.)

(In order to have China exert a larger influence in **American Hollywood**, everyone agrees that the diplomat made a great effort.)

Example 2:

Name-Congruent:

提到对于**人类科学**的影响，大家都认可爱迪生所作出的贡献。

(Mentioning to **human science** influences, everyone acknowledged Edison's contribution.)

(In terms of influences on **human science**, everyone acknowledged Edison's contribution.)

Noun-Congruent:

提到对于**人类科学**的影响，大家都认可发明家所作出的贡献。

(Mentioning to **human science** influences, everyone acknowledged inventor's contribution.)

(In terms of influences on **human science**, everyone acknowledged the inventor's contribution.)

To ensure that the sentences indeed differed in congruence, we instructed 20 participants who did not take part in the EEG experiment (and also different from the previous raters, mean age 21 years, 20–23 years old; 4 males) to rate the plausibility of the sentences on a 7-point Likert scale (7 indicates the most plausible). We found that the congruent sentences were more plausible than the incongruent sentences (Main effect of Congruence: $F_{(1,19)} = 78.67$,

Table 1 continued

Name-Incongruent:
提到对于**文艺进步**的影响，大家都认可<u>爱迪生</u>所作出的贡献。
(Mentioning to **the progress of literature and art** influences, everyone acknowledged <u>Edison</u>'s contribution.)
(In terms of influences on **the progress of literature and art**, everyone acknowledged <u>Edison</u>'s contribution.)
Noun-Incongruent:
提到对于**文艺进步**的影响，大家都认可<u>发明家</u>所作出的贡献。
(Mentioning to **the progress of literature and art** influences, everyone acknowledged <u>inventor</u>'s contribution.)
(In terms of influences on **the progress of literature and art**, everyone acknowledged the <u>inventor</u>'s contribution.)

Note: The examples were originally in Chinese, with the critical words underlined. The critical information that created incongruence in the first clause was in bold. The English translations are given in brackets below the original Chinese materials, with the word-for-word translations above the literal translations

$p < 0.001$). In addition, the sentences containing nouns were slightly more plausible than the sentences containing names (Main effect of Category: $F_{(1,19)} = 5.22$, $p = 0.034$). No interaction was found between Congruence and Category: $F_{(1,19)} = 1.364$, $p = 0.257$. The Means ± SDs are 5.00 ± 1.01, 2.11 ± 0.83, 5.11 ± 0.92 and 2.39 ± 1.06, respectively, for the Name-C, Name-IC, Noun-C and Noun-IC condition.

Since the predictability of words was found to affect N400 amplitude (Marta Kutas & Hillyard, 1984), we also tested the cloze probability of the CWs, in which we asked 20 new participants (mean age 22 years, 18–27 years old; 6 males) to complete the sentences presented up until the CWs. The CW refers to the word used in the later ERP experiment, so the cloze probability test indicates the percentage of participants that continued a sentence fragment with the CW used for the ERP study in an offline sentence completion. The CWs showed higher cloze probability in the congruent than in the incongruent condition (Main effect of Congruence: $F_{(1,19)} = 11.034$, $p = 0.004$). No difference was found between the names and the nouns (Main effect of Congruence: $F < 1$). The interaction between Congruence and Category was not significant either: $F < 1$. The Means ± SDs were 0.8 ± 1.3 %, 0 ± 0 %, 0.7 ± 1.3 % and 0 ± 0 %, respectively, for the Name-C, Name-IC, Noun-C and Noun-IC condition.

There were 88 experimental items, with each item comprising four conditions (i.e., Name-C, Name-IC, Noun-C and Noun-IC). The four conditions of each experimental item were assigned to four lists using a Latin square design. Consequently, no participant encountered (different conditions of) the same item more than once. Each of the four lists consisted of 88 items, i.e., 22 items of each condition. To avoid awareness of the experimental manipulation, we also constructed 20 filler sentences. These filler items had a similar sentence structures to the experimental sentences with 10 items containing names, while the other 10 items contained nouns. In half of the filler sentences, the incongruence occurred at a non-CW position within the second, main clause of the sentence (e.g., *提到苹果电 脑许多人都会说出乔布斯的<u>奇怪</u>。. When talking about a MacBook, many people will speak out about Job's wonder. /为了提高业绩，员工们要求老板允许<u>漏斗</u>加班。 In order to increase their performance, the employees asked the boss to allow the funnel to work late.*). The fillers were added to each of the four experimental lists. In all, each list contained 108 sentences (88 experimental items, and 20 filler items).

Procedure

Participants were seated in a comfortable chair in front of a computer screen. The words were presented in white color on a black background in an 18pt Songti font. A trial started with a fixation cross (duration 1,000 ms) in the center of the screen followed by a 300 ms blank screen. Subsequently, the sentence was presented word by word. Each word appeared for 400 ms, with an inter-stimulus interval (ISI) of 300 ms. The last word of the first clause ended with a comma, while the last word of the second clause ended with a period. Three hundred milliseconds after the presentation of the last word of the sentence, an instruction appeared on the screen in red color asking the participants to either judge the correctness of a statement based on the previous sentence within 5,000 ms, or press the "SPACE" key to continue. The participants were instructed to press the 'F' and 'J' keys on the keyboard using the left/right index fingers to signal "correct" and "incorrect", respectively. The next trial began 300 ms after the response. The statement concerned the event introduced in the sentence. Statements followed after 30 experimental sentences and 6 filler sentences, with half of them requiring the "correct" response. The adding of statements was to ensure that the participants carefully processed each entire sentence. The stimuli were divided into 4 blocks in total (27 sentences per block), with each block lasting about 4 min. The sentences were presented in a pseudo-random order, with no more than three sentences of the same condition in succession. The distribution of the statements was randomized in each stimuli list, with approximately 7–11 statements (9 statements per block on average) in each block. In between blocks, there was a small break, after which subjects could start the next block by pressing a button.

After the sentence comprehension task, the participants were asked to indicate whether they knew the famous names shown in the previous sentences. A trial started with a fixation cross (duration 1,000 ms) in the center of the screen followed by a 300 ms blank screen. Subsequently, the name was presented for 1,000 ms in a 36pt Songti font. After a blank screen lasting 300 ms, an instruction appeared on the screen in red color asking the participants to indicate whether they know the presented name within 5,000 m by pressing "F" and "J" signaling "know" and "unknown", respectively. The 44 previously seen names were presented together with 44 novel fictional names. These 88 names were presented in a randomized order in one block, which lasted about 4 min.

The participants were told not to move or blink during the presentation of words, but to blink during the presentation of the fixation cross. The whole experiment took about one and a half hour, including subject preparation, instructions and a short practice consisting of six sentences.

Electroencephalogram (EEG) recording and analysis

The data were recorded with a 64-channel NeuroScan system (10–20 system). The left mastoid electrode served as the reference, and an electrode placed between Fz and FPz electrodes served as the ground. The vertical (VEOG) and horizontal (HEOG) eye movements were monitored through four electrodes placed around the orbital region (bipolar montage). All electrode impedances were kept below 10 KΩ during the experiment. Recording was done with a band-pass filter of 0.05–100 Hz and a sampling rate of 1,000 Hz.

The EEG data were re-referenced offline to the average of both mastoids. The VEOG artifacts were automatically corrected by NeuroScan software (Semlitsch, Anderer, Schuster & Presslich, 1986). Although it is likely that any EOG artifact correction procedure creates some alternations to the original EEG data, it would not have had a systematic influence on different conditions since the procedure was applied to all the data. Additionally, no HEOG correction was conducted because this type of artifact was not prominent in our data. Data were filtered offline with a 0.01–30 Hz (24 dB/octave per slope) band-pass filter. Critical epochs ranged from 200 ms before to 1,000 ms after the onset of the CWs, with 200 ms before the onset serving as the baseline. An automatic artifact rejection procedure was taken to exclude trials exceeding ±80 μV. Additionally, the trials containing unknown names (as identified after the sentence comprehension task) and incorrect responses to the following statements were excluded from further analysis. In the end, two participants (both female) were excluded (See also *Participants*). On average, 20.9, 20.9, 21.6, 21.6 trials were kept for the Name-C, Name-IC, Noun-C and Noun-IC condition, respectively, with slightly more trials in the Noun conditions than in the Name conditions ($F_{(1,21)} = 7.05$, $p = 0.015$). The minimal number of kept trials per condition was 16.

Statistical analysis

Cluster-based random permutation test

Statistical differences between two conditions were evaluated by a cluster-based random permutation test (Maris & Oostenveld, 2007), which was implemented in the Matlab toolbox Fieldtrip (Oostenveld, Fries, Maris & Schoffelen, 2011). This approach controls the Type-I error rate, which involves multiple comparisons (one comparison for each electrode). First, for every data sample (i.e., electrode) a simple dependent-samples *t* test is performed. All spatially adjacent data samples exceeding a preset significance level (5 %) are grouped into clusters. For each cluster the sum of the *t* statistics is used in the cluster-level test statistic. Subsequently, a null distribution which assumes no difference between conditions is created. This distribution is obtained by randomly assigning the conditions (1,000 times) for subjects and subsequently calculating the largest cluster-level statistic for each randomization. Finally, the actually observed cluster-level test statistics are compared against the null distribution, and clusters falling in the highest or the lowest 2.5th percentile are considered to be significant.

On the basis of earlier studies (Kuperberg, 2007; Kutas & Hillyard, 1980; Nieuwland & Van Berkum, 2005; Sanford et al., 2011) and visual inspection, the amplitudes of the N400 and P600 were tested in the 300–500 ms and 500–1,000 ms time windows to determine statistical differences among conditions for the experimental stimuli. Therefore, the mean values of all electrodes (60 electrodes) in the selected time windows were entered into the analysis and the electrodes that showed significant effects were shown as clusters. This provides an advantage over previously used repeated measures ANOVAs as electrodes do not have to be selected and topographic factors do not have to be defined. In addition, the predefined time windows improved the statistical power of the permutation test because averaging data samples increases the signal-to-noise ratio. Although the cluster-based random permutation test only allows for pair-wise comparisons, it can accommodate a 2 $\times$ 2 experimental design, with main effects and an interaction term. For the experimental stimuli, the main effect of Congruence was tested by comparing the amplitudes of IC conditions (i.e., the averaged amplitudes of Name-IC and Noun-IC conditions) with that of C conditions (the averaged amplitudes of Name-C and Noun-C conditions). Similarly, the main effect of Category was obtained by comparing the amplitudes of Name conditions (the averaged amplitudes of Name-C and Name-IC conditions) with that of Noun conditions (the averaged amplitudes of Noun-C and Noun-IC conditions). Subsequently, the interaction between Congruence and Category was assessed by comparing two subtractions: (Name-IC–Name-C) vs. (Noun-IC–Noun-C). If the interaction effect was significant, further simple effects analyses were conducted.

Linear mixed model analysis

As mentioned earlier, the names and nouns differed in their familiarity, imageability, emotional valence and arousal. To ensure that only word Category and Congruence exerted effects on the observed ERP effects, we performed a linear mixed model analysis (LME), in which all the trials (after removing trials containing artifacts and unknown names) were entered into the analysis. This approach was chosen because LME optimally uses all available information (including both categorical and continuous variables) and therefore allows the best statistical inferences about experimental effects and individual differences (Kliegl, Wei, Dambacher, Yan & Zhou, 2011). This method has been successfully applied in recent studies (Amsel, 2011; Hauk, Davis, Ford, Pulvermüller & Marslen-Wilson, 2006; Laszlo & Federmeier, 2011; Wang et al., 2013). For all the items, the familiarity, imageability, emotional valence, arousal, number of strokes of the words, as well as the plausibility and cloze probability of the sentences were taken as independent variables. Since an interaction effect was found between Congruence and Category (see *ERP results*), we modeled the Congruence and Category effects separately. For each pair of comparisons (i.e., Name-IC vs. Name-C; Noun-IC vs. Noun-C; Noun-C vs. Name-C; Noun-IC vs. Name-IC), we took the Congruence (for the comparisons of Name-IC vs. Name-C and Noun-IC vs. Noun-IC) or Category (for the comparisons of Noun-C vs. Name-C and Noun-IC vs. Name-IC) as categorical variables. The familiarity, imageability, emotional valence, arousal, number of strokes, plausibility and cloze probability were transformed to z-values. In addition, based on the results of the cluster-based random permutation test, we averaged the ERP amplitudes in the time windows at the electrodes where significant differences between Category conditions or Congruence conditions were revealed (see "ERP Results"), for each trial and each subject, and then took these values as dependent variables.

We used the *lmer* command contained in the *lme4* package (Bates, 2010) to estimate fixed effects of the linear mixed model. This package is embedded in the *R* system for statistical computing (version 2.15.0, R Development Core Team, 2012) under the GNU General Public License (Version 2, June 1991). The contrasts of Category or Congruence and other independent variables as well as their possible interactions were specified as fixed factors, while the subjects and the items were specified as random factors. Maximal models that included both by-subject and by-item random intercepts and slopes were used to account for their possibly different sensitivities to the experimental manipulations and to generalize the fixed effects over subjects and items, as recommended by Barr, Levy, Scheepers and Tily, (2013). We started from a full model that includes all factors, and then compared the fit of this model with other models that excluded one or more factors using likelihood ratio tests (using the *anova* () function in R). We subsequently selected the simplest model that had equal fit with the full model.

Results

Behavioral results

We found that participants made highly accurate responses to the statements following all sentence conditions (all $Fs < 1.4$): Mean $\pm$ SD = 97.31 $\pm$ 3.62%; 97.72 $\pm$ .36 %, 96.69 $\pm$ 2.87 % and 96.49 $\pm$ 3.69 %, respectively, for the Name-C, Name-IC, Noun-C and Noun-IC condition. In addition, no RT differences were found between conditions (all $Fs < 1$): Mean $\pm$ SD = 1,140.89 ms $\pm$ 504.36; 1144.56 ms $\pm$ 460.83, 1178.66 ms $\pm$ 518.92 and 1195.44 ms $\pm$ 565.90, respectively, for the Name-C, Name-IC, Noun-C and Noun-IC condition.

ERP results

Statistical results of the cluster-based random permutation test

Figure 1a shows the grand average ERP waveforms evoked by the CWs in the four experimental conditions.

In the N400 time window (300–500 ms), there were significant main effects of Congruence ($p = 0.004$) and Category ($p = 0.002$). In addition, there was a significant interaction between Congruence and Category ($p = 0.03$). Simple effects analyses performed to test the Congruence effects showed a larger N400 for the IC than for the C condition concerning the names ($p = 0.016$), whereas no

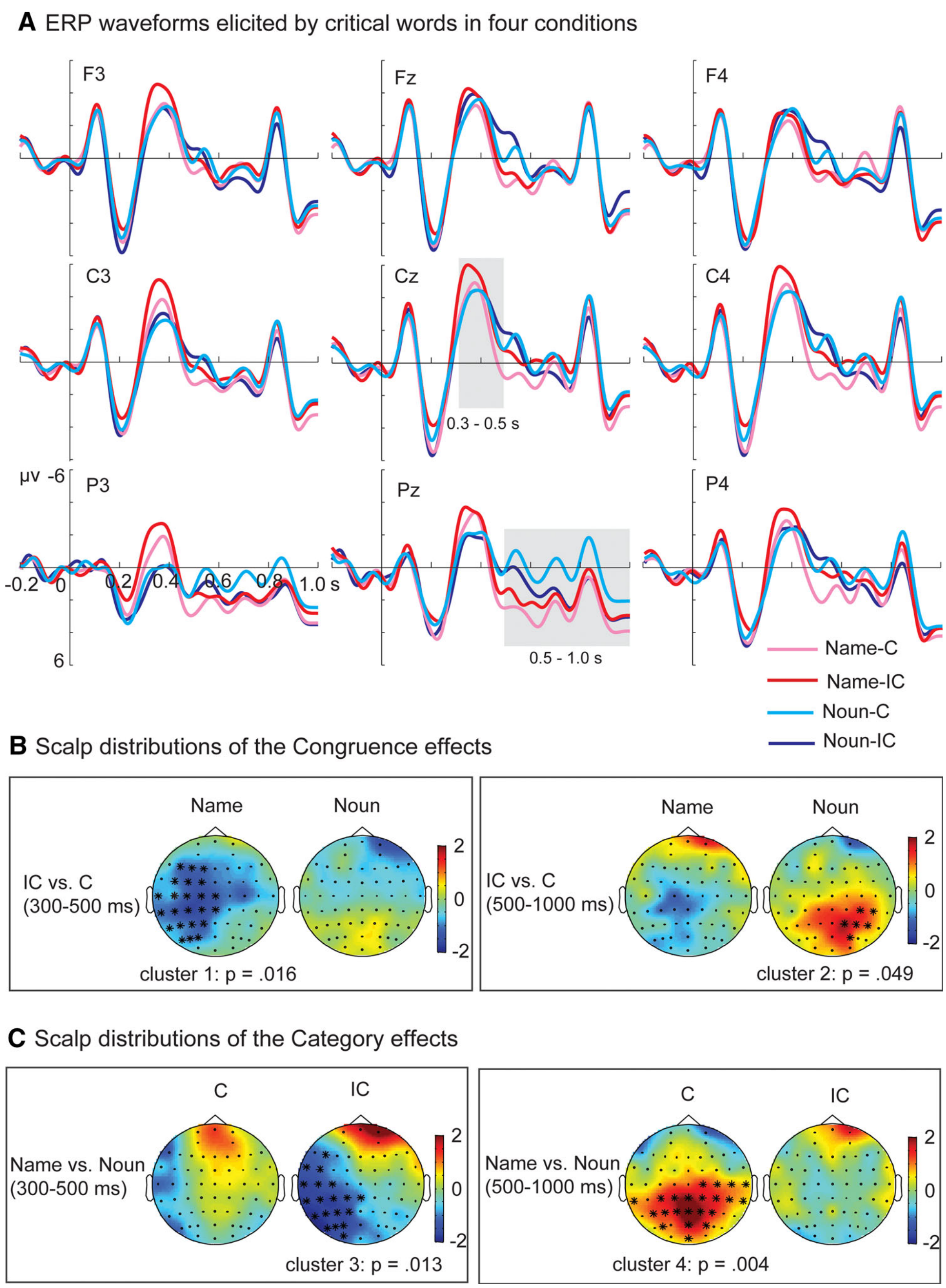

Fig. 1 ERP responses of the critical words in the four experimental conditions. **a** Grand averaged waveforms evoked by the critical words at nine representative electrodes. Waveforms are time-locked to the onset of the names. Negative is plotted upward. Waveforms were filtered with a 10 Hz low band-pass filter for illustrative purpose only. **b** The topographies of the Congruence effects for both the names and the nouns. **c** The topographies of the Category effects for both the congruence and the incongruent conditions. The electrodes that showed significant effects were marked by *asterisks*

Table 2 Fixed effects estimated with a best-fit linear mixed model for each cluster

	Estimate	SE	*t*value	*p* value
Cluster 1 (N400 effect, names): IC vs. C, 300–500 ms				
(Intercept)	−0.97	0.55	−1.76	0.078
Congruence	−1.21	0.38	−3.21	0.002
Cluster 2 (P600 effect, nouns): IC vs. C, 500–1,000 ms				
(Intercept)	0.63	0.43	1.48	0.139
Congruence	1.28	0.48	2.68	0.007
Cluster 3 (N400 effect, IC): names vs. nouns, 300–500 ms				
(Intercept)	1.77	0.37	4.77	<0.0001
Category	−1.42	0.36	−3.96	<0.0001
Cluster 4 (P600 effect, C): names vs. nouns, 500–1,000 ms				
(Intercept)	−1.71	0.40	-4.23	<0.0001
Category	1.51	0.33	4.53	<0.0001

The *p* values were based on the obtained t values and approximated degrees of freedom (the number of observations—the number of fixed effects parameters—1) as suggested by Chuang (2010). [Reference: http://www.u.arizona.edu/~ljchang/NewSite/papers/LME4_HO.pdf]

SE standard error

difference was found between the IC and C conditions regarding the nouns ($p = 0.218$). On the other hand, simple effects analyses performed to test the Category effects showed a larger N400 for the names than for the nouns in the IC condition ($p = 0.013$), whereas no difference was found between the names and the nouns in the C condition ($p = 0.133$).

In the P600 time window (500–1,000 ms), there was a significant main effect of Category ($p = 0.040$) as well as a significant interaction between Congruence and Category ($p = 0.039$). Simple effects analyses performed to test the Congruence effects showed a larger P600 for the IC than for the C condition for the nouns ($p = 0.049$), whereas no difference was found between the IC and C conditions for the names ($p = 0.109$). On the other hand, simple effects analyses performed to test the Category effects showed a larger P600 for the names than for the nouns in the C condition ($p = 0.004$) whereas no difference was found between the names and the nouns in the IC condition ($p = 0.125$). Figure 1b, c display the topographical distributions of the observed effects.

Statistical results of the linear mixed model analysis

Based on the results obtained from the cluster-based random permutation test, four linear mixed models were tested for the observed ERP effects (i.e., the N400 and P600 effects). The dependent variables of the models were obtained from the averaged ERP amplitudes of the significant clusters (combinations of time windows and electrodes, which were indicated in Fig. 1). The best-fit linear mixed model of cluster 1 (Name-IC vs. Name-C in the N400 time window) and cluster 2 (Noun-IC vs. Noun-C in the P600 time window) included only the Congruence as a fixed effect. For the models of both cluster 3 (Name-IC vs. Noun-IC in the N400 time window) and cluster 4 (Name-C vs. Noun-C in the P600 time window), only the Category was included as a fixed effect. For all the four models, both by-subject and by-item random intercepts and slopes were included. See Table 2 for the fixed effects estimated with the best-fit linear mixed model for each cluster. The significant effects of Congruence and/or Category were in line with the effects revealed in the cluster-based random permutation test. The corresponding effects obtained from the two analyses, therefore, further confirmed our findings.

Discussion

This study examined the integration of famous person names and common nouns into a sentence context. Person names and common nouns were highly related in meaning. They were either congruent or incongruent relative to the sentence context. We found that the incongruent names elicited a larger N400 compared to the congruent names in the 300–500 ms time window, whereas the incongruent nouns elicited a larger P600 than the congruent nouns in the 500–1,000 ms time window. In addition, the incongruent names elicited a larger N400 than the incongruent nouns, whereas the congruent names elicited a larger P600 than the congruent nouns. Overall, the incongruent names elicited the largest N400, while the congruent nouns elicited the smallest P600.

The meaning of person names can be rapidly retrieved in sentence context

When the meaning of a person's name was not appropriate in its context, the incongruent names elicited a larger negativity than the congruent names between 300 and 500 ms. Based on the morphology, latency, as well as the eliciting condition, we take this negative effect as an N400 effect. The N400 effect has been repeatedly reported for violations of common nouns, verbs and adjectives (for a review see Kutas & Federmeier, 2011; Baggio & Hagoort, 2011; Hagoort, Baggio & Willems, 2009; Lau, Almeida, Hines & Poeppel, 2009). Therefore, the observed N400 effect suggests that with the top–down influence of contextual information, people can indeed rapidly retrieve the meaning of person names from their long-term memory (which is mediated by person identification) and integrate the retrieved meaning into preceding context.

According to the name-processing model (Valentine et al., 1995), name retrieval involves word recognition and subsequent person identification, which implies delayed semantic retrieval of person names. Nevertheless, this model is primarily concerned with isolated names. The presentation of names in sentences allowed us to investigate the time course of name retrieval in context. Several studies have attempted to address this question. In a priming study, in which people need to judge the relatedness of a first name and a family name based on previous knowledge, a larger N400 was reported for unrelated names than related names (Proverbio et al., 2009). However, the relatedness judgment does not necessarily involve the meaning retrieval of person names. In a recent ERP study (Wang & Yang, 2013), the meaning of names was established by preceding discourse context, and then the newly established meaning was either congruent or incongruent in the target sentence. The results showed an immediate N400 effect in response to the incongruent names. However, since the incongruent names were close to the discourse context in which the meaning was established, this may have triggered rapid meaning retrieval from working memory. In the current study, the meaning of famous names had to be retrieved from long-term memory, which involves word recognition and subsequent person identification as proposed in the model by Valentine et al., (1995). Although the person names were found to be represented in a different manner in the brain compared to common nouns (Drane et al., 2008; Grabowski et al., 2001; Tranel, 2009), the processing of names in sentence contexts showed similar temporal characteristics as other categories of words (Kutas & Federmeier, 2011). The facilitation of the memory retrieval of congruent names could hence be attributed to the support of previous contexts. Therefore, the current study further tested the name-processing model (Valentine et al., 1995) in sentence context.

Interestingly, the scalp distribution of the N400 effect was more left lateralized than the centro-posterior distribution that is often observed in other studies. This might be related to the specific features of person names (Kutas & Federmeier 2011). Both neuropsychological and neuroimaging studies (Semenza, 2006, 2009; Sugiura et al., 2008) have indicated that the retrieval of person names requires the involvement of a large neural network (e.g., temporal cortex and ventro-medial prefrontal cortex). Especially, the anterior temporal cortex has been identified as important for person identification (Grabowski et al., 2001; Sugiura et al., 2006). Therefore, the left lateralized N400 effect elicited by the incongruent names might suggest that people were engaged in more effortful retrieval of the incongruent names during sentence processing. However, it is difficult to infer underlying neural sources based on the topographic distribution of the ERP effect due to EEG volume conduction. Thus, other techniques that have higher spatial resolutions (such as MEG and fMRI) are needed to substantiate this assumption. Regardless, our results supplement existing neurobiological models of language processing (Brouwer & Hoeks, 2013; Friederici, 2011; Hagoort, 2013) by demonstrating that the memory retrieval of words does not differ as a function of word category with respect to time course (e.g., person names vs. common nouns) in sentence contexts even though they are represented differently in the brain. Future studies could apply neuroimaging techniques to test the neural correlates of person name integration to broaden our understanding concerning the neural basis of memory retrieval and combinatory processing, which has been a central issue in neurobiological models of language comprehension.

"Good enough" processing of common nouns

Unexpectedly, the incongruent nouns elicited a larger positivity than the congruent nouns in the 500–1,000 ms time window over posterior regions. On the basis of its morphology, latency and distribution, we classified this positive effect as a P600 effect. Although the P600 effect was firstly related to syntactic analysis (Hagoort et al., 1993; Osterhout & Holcomb, 1992), it has also been reported in response to semantic anomalies (Kuperberg, 2007; Nieuwland & Van Berkum, 2005; Sanford et al., 2011; Van Petten & Luka, 2012). The P600 effect elicited by semantic anomalies may reflect an attempt to reinterpret the unexpected input (Kuperberg, 2007) or simply general cognitive control (Kolk & Chwilla, 2007). Similar P600 effects have been taken as evidence of temporary "good enough" processing, which indicates that people only make partial analysis of linguistic input in some circumstances (Nieuwland & Van Berkum, 2005; Sanford et al., 2011).

The occurrence of "good enough" processing depends on various factors, such as the global fit of the critical information, subjects' cognitive load and task setting (Baker & Wagner, 1987; Barton & Sanford, 1993; Glenberg, Wilkinson & Epstein, 1982; Sanford, Sanford, Filik & Molle, 2005; Sanford et al., 2011). For instance, it has been shown that when violating information fits the global context, the detection of the anomalous information elicits a P600 effect but no N400 effect (Sanford et al., 2011). The absence or reduction of the N400 effect in the case of shallow semantic processing has also been reported in other ERP studies (Wang et al., 2009, 2011), in which the violating information was located in a non-focus position. In addition, behavioral data have shown that people engage in shallow processing when the sentences are harder to process and require more processing effort (e.g., long vs. short texts: Glenberg et al., 1982; subordinate vs. main clauses: Baker & Wagner, 1987; object vs. subject relative clauses: Sanford et al., 2005). Also, the detection of semantic anomalies was found to decline when the task instructions emphasized speed rather than accuracy (Jaarsveld, Dijkstra & Hermans, 1997).

In the present study, the first clause set-up a global context (e.g., "In terms of influences on human science/the progress of literature and art"), the second clause (e.g., "everyone acknowledged the inventor's contribution") contained a common noun (i.e., *"inventor"*) that shared some properties with the global context (such as "having great influences") and had relatively low specificity. Also, people could only detect the incongruence if they effectively kept the contextual information in mind until reading the critical information. People might tend to superficially analyze the words and it might have therefore been difficult to immediately detect the incongruence (e.g., "inventor" has no direct influence on the progress of literature and art.). However, since the incongruence was still rather obvious (based on the rating score of the plausibility of the sentences), we speculate that participants did ultimately detect the incongruence, leading to a P600 (and thus a temporary good enough processing). Regardless of the P600, the lack of the N400 effect indicates that the full meaning of the noun was either not retrieved or not integrated into the mental representation of the discourse.

Another possibility is that the participants did not have sufficient information to judge whether the sentence made sense at the position of the critical nouns. To test this possibility, we performed a post-test in which 20 new participants (i.e., who did not participant in the ERP experiment or the pre-tests; mean age, 22 years; range 21–25 years; 3 males) were asked to rate the congruence of the sentence fragments up till the critical words on a 7-point Likert scale. We found that the congruent sentences were more plausible than the incongruent sentences (Main effect of Congruence: $F_{(1,19)} = 141.78, p < 0.001$), and the sentences containing nouns were more plausible than the sentences containing names (Main effect of Category: $F_{(1,19)} = 6.60$, $p = 0.019$). Moreover, there was a significant interaction between Congruence and Category ($F_{(1,19)} = 5.91$, $p = 0.025$), indicating that the congruence effect was larger for person names than for common nouns. The Means ± SDs were 5.55 ± 0.41, 2.70 ± 0.87, 5.58 ± 0.59 and 3.11 ± 0.89, respectively, for the Name-C, Name-IC, Noun-C and Noun-IC condition. This post-test of the sentence fragments suggests that participants indeed took the incongruent sentences as being anomalous even with limited information, as indicated by the rating scores of the incongruent sentences (below 4 on the 7-point scale). Moreover, the relatively higher score for the incongruent common nouns (3.11 vs. 2.70, respectively, for noun-IC and name-IC conditions) concurs with the observed ERP effects, i.e., the lack of an N400 effect for the incongruent nouns. Although, observably, the difference was small (likely due to a lesser sensitivity of the offline ratings than ERPs), the higher acceptability of the incongruent nouns compared to names in the same sentential contexts further supports the assumption that nouns shared more properties with the global contexts than names probably due to their relatively lower degree of specificity. It is conceivable that an N400 effect might be present if stimuli were constructed in a slightly different way. For instance, the use of critical words in the final position of the sentence might render the incongruent sentence being more noticeable (resulting in an N400 effect) since people tend to have stronger predictions towards the end of the sentence (e.g., "… everyone acknowledged the significant contribution of the inventor"). Although the current set of stimuli does not fully represent all possible types of sentence context, it provides a sensitive measure of the processing differences between person names and common nouns in sentence context. More studies are needed to fully understand the circumstances in which person names and common nouns are processed in similar or different manners.

One might argue that the lack of an N400 effect could be due to overlapping components between N400 and P600 in a way that the later P600 masked the preceding N400 effect. However, this would not be in line with reports from previous studies showing a biphasic N400/P600 pattern, that is, showing that a larger N400 can be readily followed by a larger P600 [e.g., (Frenzel, Schlesewsky & Bornkessel-Schlesewsky, 2011; Tune et al., 2014; van de Meerendonk, Kolk, Vissers & Chwilla, 2010)]. Also, independent occurrences of N400 and P600 effects have been reported in response to semantic violations

(Nieuwland & Van Berkum, 2005; Sanford et al., 2011; Tune et al., 2014). Therefore, we believe that the N400 effect associated with anomalous detection and the P600 effect associated with monitoring (or conscious awareness of the anomalies, or reanalysis of the inputs) could be independent in terms of underlying cognitive processes, and thus it is unlikely that the P600 effect occurs early in the N400 time window. However, admittedly, it is difficult to fully rule out the possibility of overlapping components in our data, as we found no such biphasic pattern in response to anomalies. Because the P600 effect was shown to be sensitive to task requirement, with a larger P600 effect during a sentence plausibility task compared to reading for comprehension task (e.g. (Kuperberg, 2007; Vissers, Chwilla & Kolk, 2007), future studies could use a broader range of tasks to see whether the modulated P600 effect has any influence on the preceding N400 effect.

The processing differences between person names and common nouns

The incongruent names elicited an N400 effect whereas the incongruent nouns showed a P600 effect. The interesting question then is why only "good enough" processing occurred for common nouns but not for person names. This discrepancy might be explained by the fact that the semantic associations of common nouns are richer than that of person names. For common nouns, multiple semantic links converge to form its meaning. In contrast, for person names, identify-specific information converges on the person identity node, which connects to a specific person's name via a single connection. Additionally, the precise information about the name bearers' attributes, accomplishments and status in society is often unique. These highly exclusive semantic associations put particular well-known individuals into semantic categories that have no other members (Grabowski et al., 2001). In this sense, the semantic specificity spans from unique for person names (such as "Thomas Edison") to less-specific for common nouns (such as "inventor"). Since the occurrence of "good enough" processing is influenced by the semantic associations between the critical information and the contextual information, the high specificity of person names relative to common nouns might explain why person names are more immune to the "good enough" processing strategy. The slightly higher plausibility of the sentences containing nouns than names also supports this assumption.

When comparing names with nouns, the incongruent nouns elicited a smaller N400 than the incongruent names. It is known that the N400 can be attenuated by a high degree of association between a word and other context words (Kutas & Federmeier, 2011). This provides further evidence for the notion that the semantic associations of common nouns are richer than that of person names (due to different levels of specificity), leading to a greater support from the context on the retrieval of incongruent nouns than incongruent names. Following the N400 component, the congruent names elicited a larger P600 than the congruent nouns, which might indicate prolonged integration of the congruent names into the mental representation of the sentences. One might speculate, however, whether the different ERP responses between person names and common nouns might simply be accounted for by their lexical-level differences. Indeed, compared to the nouns, the names were rated to be more familiar, more imaginable, more positive and more arousing. These differences related to the high specificity of person names. To avoid any confounds from lexical-level variability, we included all the variables into a linear regression analysis. The result from this analysis excluded this alternative explanation.

Conclusions

This study examined how famous person names and common nouns are integrated into sentence context. Highly related names and nouns were separately embedded in the same sentence contexts, within which the names and nouns were either semantically congruent or incongruent. We found that incongruent names elicited a larger N400 than congruent names, whereas incongruent nouns evoked a larger P600 than congruent nouns. The results suggest that people are able to rapidly retrieve the meaning of person names from their long-term memory and integrate the meaning into a sentence context even though the activation of a name's meaning is mediated by a single connection between identity-specific information and person identity node. The observation of the N400 effect supplements existing neurobiological models of language processing by demonstrating that the memory retrieval of words does not differ as a function of word category in terms of time course (e.g., person names vs. common nouns) in sentence context. However, a "good enough" processing (Ferreira & Patson, 2007; Sanford & Graesser, 2006) occurred for common nouns due to their low level of specificity and thus rich semantic associations, supporting the notion that common nouns are represented differently from person names in the brain.

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