Syntactic planning and lexical access in written and spoken sentence production

In order to initiate the production of a simple sentence, a minimal linguistic unit needs to be prepared. The size of this unit is know to be subject to extra-linguistic factors (e.g., Ferreira and Swets, 2002; Konopka, 2012; Swets et al., 2014; Wagner et al., 2010). However, many researchers agree on the first phrase to be the minimal syntactic planning unit in sentence production (e.g., Allum and Wheeldon, 2007, 2009; Martin et al., 2010, 2014; Smith and Wheeldon, 1999; Wheeldon et al., 2013). The relation between this syntactic unit and the preparation of lexical material is theoretically controversial (Wheeldon, 2011; Wheeldon et al., 2011). Some language production theories claim lexical access to be conceptually mediated (Bock and Levelt, 1994; Ferreira, 2000; Ferreira and Slevc, 2007; Wheeldon et al., 2013). Therefore lexical access needs to proceed syntactic planning. Others propose that the syntactic unit is directly based on a conceptual structure while lexical access is subsequent to syntactic planning (Chang et al., 2000, 2003, 2006; Lee et al., 2013). While these discussions focused on the spoken production modality, written sentence production has been widely ignored. Available data suggest that syntactic planning in writing is more restricted than in speech embracing the first noun phrase along with subordinated but not coordinated noun phrases (Nottbusch, 2010; Nottbusch et al., 2007; Torrance and Nottbusch, 2012). In this study we address the question whether or not lexical access exceeds the minimal unit of syntactic planning and examine how syntactic planning and lexical access are being coordinated in the spoken and written output modality.

(1) a. Peter and the *N2* moved up and Tania moved down.
b. Peter moved up and the *N2* and Tania moved down.

(2) a. Peter and the *N2* moved above the bird.
b. Peter moved above the *N2* and the bird.

In two experiments English natives (n=32 each) were shown moving arrays of familiarised images of *Peter* and *Tania* and coloured images of common items (Rossion and Pourtois, 2004). Participants were instructed to produce sentences such as (1) in Exp. 1 and sentences as shown in (2) in Exp. 2. Each participant performed in a spoken and a written (i.e., typing on a keyboard) session. We manipulated the complexity of the first syntactic phrase and the ease of lexical access of the second noun (N2). In both experiments the first phrase was either a complex coordinated noun phrase, i.e., *Peter and the N2* in (1-a), (2-a), or a simple noun, i.e., *Peter* in (1-b), (2-b). The ease of lexical access of N2 was manipulated differently in Exp. 1 and 2. In Exp. 1 the codability of the image corresponding to N2 was manipulated. Codability is an indicator of the amount of names for an image which is known to correlate with lexical accessibility (Griffin, 2001). For instance, according to codability estimates from picture naming data, an image of a *bell* has fewer names (i.e., high codability) than an image of a *hat* (i.e., low codability). In Exp. 2 semantic priming was used to manipulate lexical access of N2. Boundary triggers were used to associate fixations on the image corresponding to N2 with either the most commonly used image name or a length matched pseudo-word. 96 items were counterbalanced for subject complexity, prime-word type (experiment 2), and output modality. The order of the spoken and the written session was balanced as between-subject factor. Each list included 44 fillers and was presented randomly. To estimate planning effort prior to production onset we recorded eye movements on the image corresponding to N2, and the to-response onset latency.

If the phrase is the syntactic planning unit (e.g., Smith and Wheeldon, 1999), complex subject phrases are predicted to reveal more planning effort prior to production onset than simple subject phrases. Furthermore, if lexical access is conceptually mediated and thus restricted by the minimal syntactic unit, the lexical access manipulation is predicted to affect complex subjects only. However, if there is the syntactic structure is built on the conceptual plan, the planning effort should

not be facilitated by the lexical access manipulation prior to production onset, but subsequent to production onset.

The Bayesian linear mixed models were used for the analysis of the elog of the proportions of fixations on the image corresponding to the second noun prior to production onset and the log to-production onset latency. The data of the fixation proportions on the image corresponding to the second noun prior to production onset are shown in Fig. 1 (left panel). The analysis of the data of experiment 1 revealed evidence for a main effect of subject type ($\hat{\beta}$ = 0.89, 95% CrI [0.71, 1.08]) showing more fixations for complex subject phrases than for simple subject phrases and a main effect of codability ($\hat{\beta}$ = 0.18, 95% CrI [–0.02, 0.29]) showing more fixations for low codable than high codable images. Further, evidence for an interaction of subject type and modality was found ($\hat{\beta}$ = 0.34, 95% CrI [0.18, 0.49]) driven by a larger subject type effect in the spoken modality than in the written modality. The fixation data of experiment 2 are shown in Fig. 1 (right panel). The analysis provided evidence for a main effect of subject type ($\hat{\beta}$ = 0.71, 95% CrI [0.51, 0.90]) showing more fixations in complex subject phrases compared to simple subject phrases and evidence for a main effect of modality ($\hat{\beta}$ = –0.60, 95% CrI [–0.88, –0.31]) showing more fixations in speech than in writing. Further, the analysis revealed evidence for an interaction of prime type by subject type by modality driven by more fixations for pseudo word primes compared to image name primes in complex subject phrases for speech but less fixations for pseudo word primes in simple subject phrases for speech and complex subject phrases in writing. No evidence for a priming effect was seen in simple subject phrases for writing. The results of the onset latency are visualised in Fig. 2. The analysis of the data of experiment 1 provided evidence for a main effect of subject type ($\hat{\beta}$ = 0.03, 95% CrI [0.02, 0.05]) showing longer latency for complex compared to simple subject phrases. Evidence for an interaction of codability by subject type ($\hat{\beta}$ = 0.02, 95% CrI [0.00, 0.03]) revealed longer latency for low codable images compared to high codable images for complex subject phrases. No such effect was seen for simple subject phrases (see left panel of Fig. 2). The analysis of the onset latency of experiment 2 revealed a main effect of subject complexity ($\hat{\beta}$ = 0.04, 95% CrI [0.02, 0.05]) showing longer durations for complex than for simple subject phrases and a main effect of modality ($\hat{\beta}$ = 0.08, 95% CrI [0.05, 0.12]) showing longer latencies for writing than for speech. Further, evidence was found for an interaction of modality by subject complexity by prime ($\hat{\beta}$ = 0.02, 95% CrI [0.00, 0.03]) which is driven by a longer latency for pseudo prime words compared to prime words for complex subject phrases in speech and a tendentiously shorter latency for pseudo prime words compared to prime words in writing. As for simple subject phrases we found weak evidence for a shorter latency for pseudo prime words in speech but no compelling evidence of a priming effect for simple subject phrases in writing (see right panel in Fig. 2).

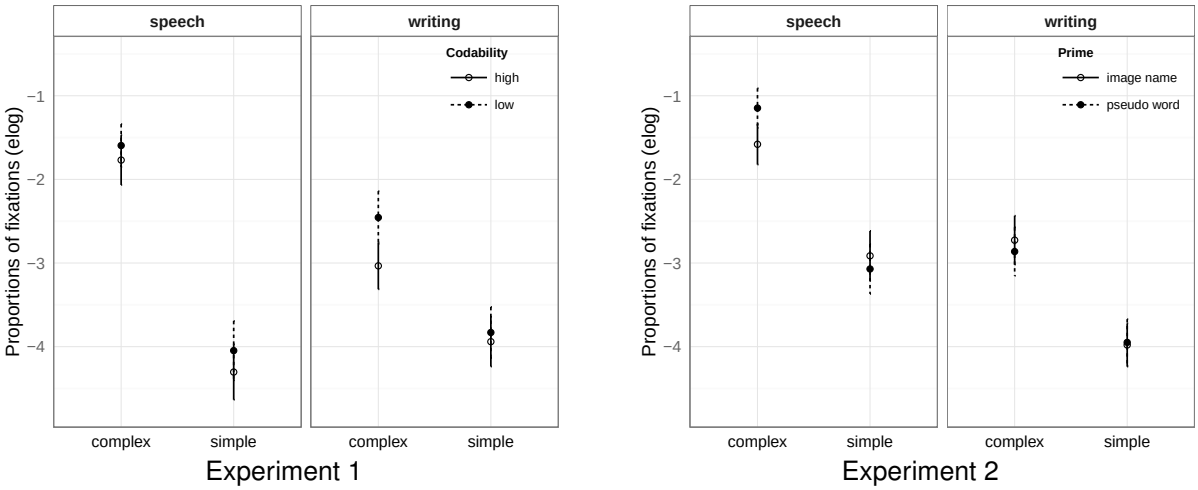

Fig. 1: Fixations on image of N2 prior to production onset (with 95 % CIs)

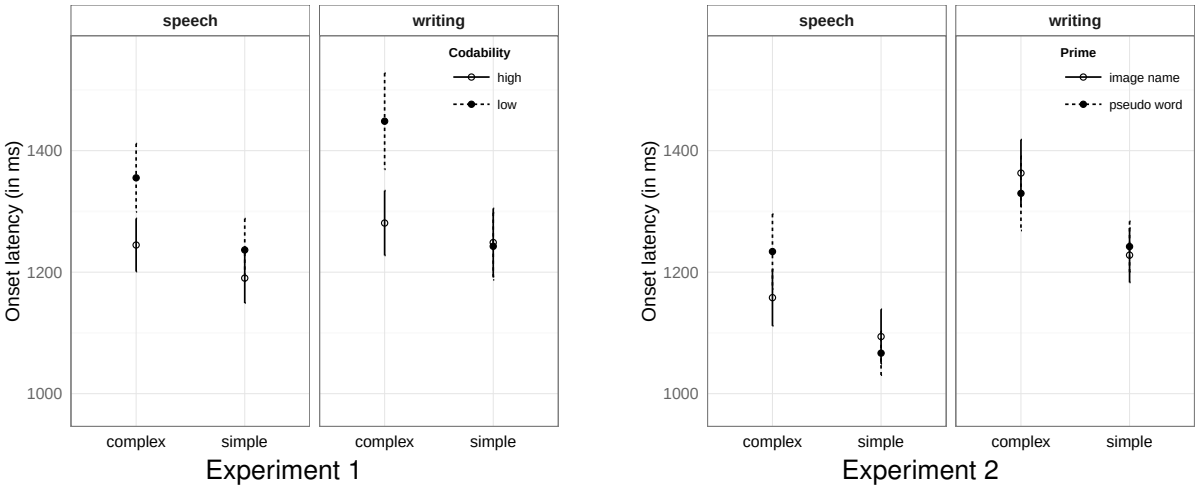

Fig. 2: To-production onset latency (with 95 % CIs)

These results replicated the phrasal planning scope for both speech (e.g., Smith and Wheeldon, 1999) and writing. Further, we provided evidence that the lexical access of the second image is restricted to sentence with complex subjects. Lexical access has not been prepared if the second image was not part the first noun phrase. Therefore, the syntactic planning unit restricts lexical access. This finding is in line with sentence production accounts that assume that lexical access is conceptually mediated (e.g., Bock and Levelt, 1994; Wheeldon et al., 2013). Moreover, more the modality effect observed in experiment 2 was absent in experiment 1. The modality effect is assumed to reflect executive difficulty in the written modality. However, this difference is absent in experiment 1. We suggest that the planning effort dedicated to the more complex target sentences in experiment 1 compared to experiment 2 was elevated in speech but not in writing. In line with Smith and Wheeldon (1999), spoken sentence planning seems to exceed the first phrase on the conceptual level. In writing, however, sentence planning does not seem to last beyond the first syntactic phrase. We conclude that the noun phrase as the syntactic planning unit in both writing and speech. However, lexical planning for complex noun phrases was found to be more thoroughly in speech than in writing. Additionally, conceptual planning of the target sentence seem

to exceed the first noun phrase in speech (see Brown-Schmidt and Tanenhaus, 2006; Smith and Wheeldon, 1999; Swets et al., 2014) but not in writing.

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