Scientific report – NetWordS Grant 3777

Compound processing – a cross-linguistic perspective

1. Purpose of the visit

The purpose of my 12-weeks exchange visit to Helsinki, Finland (5th September – 25th November 2012) was to study compounds in a cross-linguistic environment, in close collaboration with Dr. Minna Lehtonen of the Cognitive Brain Research Unit (CBRU) of the University of Helsinki.

We chose this approach, because direct cross-linguistic comparisons hardly seem to exist. Psycholinguistic research units across the world work hard to disclose phenomena of language comprehension and production, and in general they use their own country's native language as a pool to provide stimuli (Winther Balling & Baayen, 2008, for Danish; Perea & Carreiras, 2008, for Spanish; Rastle et al., 2004, for English; Zwitserlood, 1994, for Dutch; Lüttmann et al., 2011, for German; Soveri et al., 2007, for Finnish). But as is often the case, scientific results do not always agree. For example, the findings reported by Fiorentino & Poeppel, 2007, differ considerably from those reported by Lehtonen et al., 2007, and also the data reported by Giraudo & Grainger (2001) seem difficult to reconcile with the findings of Taft & Ardasinski (2006). Taking a closer look at studies using the same paradigm in different languages, it becomes apparent that these studies often differ in more than just the language. Different presentation times, and quite often even stimuli from different word classes are used to test specific issues, but when the results are compared to the findings of a research group from another country, interpretation becomes difficult. Because more than just the language parameter was altered, it is indecisive whether empirical discrepancies have their origin in the experimental design, or in the languages used. Given that theories often claim to be "universal" with respect to the processes and principles they capture, similar results are expected for different languages. This implicitly also holds for theories of morphological processing and representation, our area of interest. In our opinion, the assumption that the language itself does not have an influence on the experimental outcome should not remain unexamined.

For this reason and focusing on word-internal complexity, we designed a set of four experiments using noun-noun compounds and monomorphemic words as stimuli, because this is where Finnish and German can best be compared.

Finnish and German are very dissimilar at the word and sentence level (making them ideal candidates for a cross-linguistic approach), but the nominative forms of nouns are built in the same way, for example, “kukkakaali” and “Blumenkohl” (“cauliflower” in Finnish and German). For compounds, nouns are merely attached to each other, sometimes using a binding-morpheme, but neither Finnish nor German tends to write compounds as separate words (as it is often found in English: “front door”).
The basic structure of nominative forms is practically identical in both languages, but unlike German, inflected Finnish nouns often carry a whole string of morphemes, since Finnish – belonging to the family of agglutinating languages – uses morphemes attached to a stem instead of prepositions, possessive pronouns and so on: “talo/i/ssa/mme/kin” would be “auch in unseren Häusern” in German, and “also in our houses” in English. We therefore only used uninflected nominative forms.

The general aim of our experiments was to study compounds in comparison to simple words, and to explore the time course of the processing of these words in order to draw conclusions about the way in which such words are represented in the mental lexicon (full-form storage versus storage of decomposed forms). In all our experiments, we matched noun-noun compounds item by item with monomorphemic words in frequency (both surface and lemma frequency) and length. At the same time we were careful only to choose compounds whose constituents were of a higher frequency than the whole compound. This leaves compounds with a head start in processing relative to monomorphemic words, so that shorter latencies should be found for compounds in case of decomposition.
Because we were also interested in the level of processing at which possible differences occur, we used different tasks that taxed different processing levels, and EEG to study the time course of processing, and, of course, we also varied the language to study its effects.

2. Description of the work carried out during the visit

The project consisted of 4 experiments, each in Finnish and German, which did not differ between the two languages in their general outline. As the German experiments had already been conducted earlier in Germany, work during the exchange visit focused on the Finnish experiments.

In our first experiment (Experiment 1), transparent noun-noun compounds were selected to form pairs with a shared constituent and a non-shared constituent of either high or low frequency. These compounds were matched item by item with a monomorphemic word, with respect to length, surface frequency, and lemma frequency (**ajokortti**/**ajoneuvo**/**mansikka** (driving license/driving consulting/strawberry); for better legibility, in this example frequency and constituent structure are colour-coded). Constituent frequency was always higher than surface frequency. Because only 14 triplets matching all these criteria could be found, we expanded the stimulus set by adding 50 transparent noun-noun compounds, which were matched to simple words according to the same criteria as mentioned above. Constituent frequency was always higher than surface frequency. The 50 pairs were assigned to a "high" or a "low" frequency group according to the mean constituent frequency of the compounds, in order to imitate the triplets as closely as possible (**apu.raha**/**kynttilä** --- **joulu.yö**/**varpunen** (scholarship/candle --- Christmas Eve/sparrow) ; the dots within the compounds are inserted to clarify the constituent structure of the compounds).
The subjects performed a visual lexical decision task on the word stimuli and on pseudowords. We used distorted noun-noun compounds (***hesinukke**, ***hillomumppi**, ***rassemako** [original: käsi.nukke, hillo.munkki, kaste.mato (hand puppet, jam doughnut, earthworm); the dots within the compounds are inserted to clarify the constituent structure of the compounds]), distorted monomorphemic words (***tämäräkki** [original: hämähäkki (spider)], and illegal combinations of legal constituents (***avolusikka** [avo.lusikka (marriage spoon)]). For better legibility we will use English examples for pseudowords in the rest of this text.
By assigning the two versions of pseudo-compounds to different experimental groups (E1a, E1b), we taxed different processing levels (in order to perform a visual lexical decision task on pseudo-compounds made up from legal constituents, such as "pasta mouse", the participants need to fully process and evaluate each stimulus, thus making this task more difficult than to recognize a pseudo-compound made up by distorting an existing compound,

such as “tustard seep” [original: mustard seed]). Fifty-four members of the University of Helsinki (mostly students) participated in Experiment 1 (27 in E1a, 27 in E1b). Reaction times were measured.

In our second experiment (Experiment 2), 36 single opaque noun-noun compounds were matched with a monomorphemic word in length, surface frequency and lemma frequency (**lohi.käärme/keramiikka** (dragon [verbatim: salmon snake]/pottery); the dot in lohikäärme indicates the compound’s constituent structure for better legibility of this text). Again, constituent frequency was always higher than surface frequency. We checked the semantic opacity of the compounds in a transparency rating with 89 participants.
The subjects performed a visual lexical decision task on the stimuli and pseudowords (distorted noun-noun compounds, distorted monomorphemic words, and illegal combinations of legal constituents). By assigning the two versions of pseudo-compounds to different experimental groups (E2a, E2b), we taxed different processing levels in the same way as in Experiment 1. Forty-three members of the University of Helsinki (mostly students) participated in Experiment 2 (22 in E2a, 21 in E2b). Reaction times were measured.

In our third experiment (Experiment 3) noun-noun compounds and monomorphemic words were again matched with respect to word length, surface frequency, and lemma frequency. These pairs were divided into a group of high frequency words, and a group of low frequency words, based on their surface frequency (**lumi.pyry/leikkuri** --- **turva.vyö/tulppaani** (snow storm/cutter --- security belt/tulip); the dots in lumipyry and turvavyö indicate the constituent structure of the compounds for better legibility of this text). Constituent frequency did not vary between the groups. The subjects performed a visual lexical decision task on the stimuli and pseudowords (distorted noun-noun compounds, distorted monomorphemic words, and illegal combinations of legal constituents). By assigning the two versions of pseudo-compounds to different experimental groups (E3a, E3b), we taxed different processing levels in the same way as in Experiments 1 and 2. Forty-one members of the University of Helsinki (mostly students) participated in Experiment 3 (20 in E3a, 21 in E3b). Reaction times were measured, and EEG was recorded.

In our fourth and last experiment (Experiment 4), we again used noun-noun compounds and monomorphemic words, matched in word length, surface frequency, and lemma frequency. With respect to the property “man-made” or “nature-made”, the constituents of the

compounds were either congruent or incongruent to the whole word (**vene.satama**/**kaasu.putki**/**monumentti** (boat harbour/gas pipe/monument); the dots in venesatama and kaasuputki indicate the constituent structure of the compounds for better legibility of this text). We selected 64 triplets (32 man-made, 32 nature-made). The subjects were to perform a semantic categorization task, rating whether the words were man-made or nature-made. (If compounds are decomposed into their constituents, longer latencies and higher error rates are expected for the incongruent stimuli.)
In our original Project Description, we had estimated the time needed to complete the project at 4 months, and reality proved us right. Despite taking every imaginable effort to complete experimental setup and data collection within 12 weeks, time was too short. As a consequence of this, I had to leave Helsinki before I could collect the data for Experiment 4.

All work was carried out in close collaboration with Dr. Lehtonen and laboratory engineers Miika Leminen and Tommi Makkonen from the CBRU. During my stay in Finland, I also visited Dr. Raymond Bertram at the University of Turku to discuss the possible influence of word length on the outcome of the experiments. I did not want to start interpreting my data without his opinion, because he is an expert in this field and has previously studied Finnish compounds in eye-tracking studies.

3. Description of the main results obtained

One possible outcome – the desired one for many theories – is that the results for the two languages are very similar, given the similarity of the stimuli used (nominative noun-noun compounds and monomorphemic words), and despite language differences between Finnish and German. This is what we expected to happen.
In all German experiments, we found strong signs of decomposition during the processing of compounds. This is supported by the analyses of reaction times and error rates. We repeatedly found shorter latencies for compounds, which have a head start in processing relative to monomorphemic words, due to the higher frequency of their constituents. The processing costs for the integration of the constituents into a whole word seemed to be so small that the compounds were still recognized significantly faster than matched monomorphemic words. Only in experimental designs that had a strong weight on correct integration (a combination of OPAQUE compounds AND pseudo-words made up from legal constituents, as used in

Experiment 2b), the integration costs became so high that they consumed the head start the compounds gained from their constituents' frequency.

Looking at latencies and error rates in the Finnish experiments, a somewhat different view unfolds. The error-rates are smaller than in the German experiments (perhaps due to the fact that written and spoken Finnish are much closer phonetically than written and spoken German). Low-frequency words tended to cause higher error rates than high-frequency words – a finding that does not surprise, and is in line with the German experiments. Also, in all Finnish and German experiments, a higher error rate was observed for pseudo-compounds that were distorted in the second constituent, compared to pseudo-compounds whose first constituent was altered ("mustard seep" is harder to reject as a word than "tustard seed" [original: "mustard seed"]). This seems to fit well with decomposition. Also, the triplets-version of the Finnish Experiments 1a and 1b yielded a pattern comparable to the German Experiments E1a and E1b: Compounds were recognized significantly faster than monomorphemic words, and high-frequent compounds were recognized faster than low-frequent compounds. This also points towards decomposition, but, as mentioned above, there were only 14 triplets. In the pairs-version of Experiment 1, compounds were still recognized faster numerically, yet not statistically. The same pattern was found for the Finnish Experiment 2. In Experiment 2a, opaque compounds were recognized numerically, yet not statistically, faster than the matched simple words. In Experiment 2b, there were also no statistical differences in the data. (Remember that also German participants did not respond faster to opaque compounds than to morphologically simple words in this context). In the Finnish Experiment 3, absolutely no differences between compounds and simple words could be found in the latency data, both in the E3a and E3b version of the experiment. For the EEG-data of Experiment 3, analyses are still on-going. We regret that we cannot make a statement on the EEG-results yet, but extensive analyses of EEG-data take time.

To sum up, German reaction times and error rates point towards decomposition. Finnish error rates also point towards decomposition. Finnish reaction times sometimes show a tendency towards decomposition, but judging from mere statistics, evidence speaks in favour of the existence of whole-word forms for compounds in Finnish, or of decomposition and really high integration costs. Our current interpretation is as follows: In Finnish, it is very important to decipher morpheme boundaries in words, in order to understand the grammatical relations between the parts. Due to the agglutinating nature of the language, this is also more difficult than in a language with fewer morphemes in most complex words. The Finnish plural-marker morpheme, for instance, is a single "i" between a word's stem and other morphemes, and correct integration of morphemes is crucial for understanding. So for Finnish, higher processing costs are expected in general. They might not be needed for plain uninflected noun-noun compounds, but a general tendency to invest rather some more milliseconds in correct integration of constituent morphemes might make understanding Finnish for Finnish speakers more accurate, not just in our artificial laboratory-settings, but in everyday-life. In German, this is not needed, because complex words in German are still less complex than an average Finnish complex word. According to this hypothesis, one might expect a fast, but error-prone integration in German, because in comparison to Finnish there are fewer morphemes to be segmented properly in an average word, and German speakers do not have to focus that much on recombination (compared to Finnish speakers). Of course, speakers will apply strategies and heuristics that work well in everyday-life on problems presented to them in a rather artificial lab context. So, there seems to be decomposition in Finnish, too, but at a high integration cost.

4. Future collaboration with host institution

As mentioned earlier, data collection for Experiment 4 is still pending. Besides this, future collaboration is highly desirable in general.

5. Projected publications / articles to result from the grant

We intend to write up our results for publication to a suitable scientific journal next year (one paper on the Finnish experiments). Furthermore, selected results will be presented at conferences. At the moment, a talk about the Finnish and German Experiment 3 has been accepted for the TeaP, held in Vienna in March 2013.

6. Other comments

I would like to use this space to express my thankfulness to the ESF for enabling me to go to Helsinki for an exchange visit. Working at the CBRU helped me to broaden my theoretical and practical scientific knowledge in a way that simply would not have been possible without

this exchange visit. Working on the project was like building a bridge, not just between languages, but also between research groups, and the cross-linguistic approach revealed things that would not have been visible if we had studied only one language.

Münster, 23rd January 2013

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