Time patterns in visual reception and written phrase production[1]

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Abstract

In previous studies we could show that linguistic word structures correlate closely with the time course of written word production. In the present study we investigate whether there are also correlations between the syntactic structures of phrases and the time course of their production. Using the findings from a combination of keyboard and eye tracker data, this paper shows that our results back up the intuitive theory that phrase structures that are syntactically different are perceived, planned and processed differently. Using this data we also show that when extra-conceptual processes are present the perception and planning processes are significantly affected.

Introduction

Language production has been the subject of research from a number of different angles in the last few years. Most of the research, though, has focused on understanding the underlying processes responsible for the production and planning of spoken words and phrases. Models giving plausible explanations of what and how the processes of speech production function have been put forward by Dell (1986), Levelt (1989), Dell and O'Seaghdha (1991), Bock and Levelt (1994) and Levelt, Roelofs and Meyer (1999).

An area of language production that has been less researched is the area of written language production. This is due to the view that the time course of writing is determined, to a large extent, by motoric aspects. Although several studies dealing with handwriting and typing as skilled motor tasks led to interesting findings regarding the organisation of motor processes involved (e.g. van Galen (1991) dealing with handwriting and Cooper (1983) dealing with typing), only a few studies were conducted regarding the central cognitive processes underlying written language production.

Ellis (1982) hinted at the influence of higher processes on the time course of writing. Van Galen (1990) found shortened initial latencies and lengthened writing times of words after syllable repetitions in handwriting. Zesiger et al. (1994) found increased interkey intervals (IKI's) [2] for within-word syllable boundaries in typewriting but no effects on reaction time or production time in handwriting. For a more in depth discussion see Will et al. (submitted). The research that has been carried out in this field has, up to now, concentrated on the written word level. Weingarten (1997) and Nottbusch et al. (1998) present evidence suggesting that the linguistic units of the words themselves play an important role in defining the time structures of handwriting. These results are also consistent with further experimental data, which showed that the same pattern was visible in the time course of interkey intervals while typing words. This would point to the fact that each word is planned and produced (written) according to a certain kind of "rhythm" which becomes visible in the time course analysis of the word. This "rhythm" is affected by such factors as: differences in word frequency, number of letters in the word, positioning of the keys on the keyboard used during writing/typing etc. On the level of linguistic structures, it has been found that this "rhythm" is very sensitive to the types of boundary (e.g. syllable, morpheme, syllable-morpheme boundaries) and the number of boundaries (within the word) making up the word. Figure 1 displays what is meant by "rhythm" during the production of a word. It also shows very clearly the effects different within-word boundaries have on the way in which the same letter string, in this case */nd/*, appearing in different words is affected. As can be seen the strings within the different words are produced according to surprisingly different time courses.

In figure 1 it can be seen that all of the words have the same letter string covering positions two to four. In each of the conditions, different within-word boundaries operate between positions three and four and create the course of events depicted. We are only interested in the */nd/* transition though, because here the motoric constraints are the same for each word although one finds different kinds of linguistic borders between the two letters. In the case of *hindurch* (through) the IKI between */n/* and */d/* represents the border between two basic morphemes, as well as a syllable border. This results in the IKI time interval between the */n/* and the */d/* being produced slower than the IKI required for the production of the */n/*. The IKI between */n/* and */d/* in the word *Linde* (limewood) is influenced, in this case, by a syllable border only. As this is the case it is seen to be produced faster than the */nd/* IKI of *hindurch*. The same pattern is present for the final word, *Kind* (child). The */nd/* IKI represents neither a syllable-morpheme boundary nor a syllable boundary and as such it is produced in the fastest time course of the three words. When all three words are overlaid it becomes clear that different processes influence the production of this (identical) string of letters when they are part of words differing in their linguistic structure.

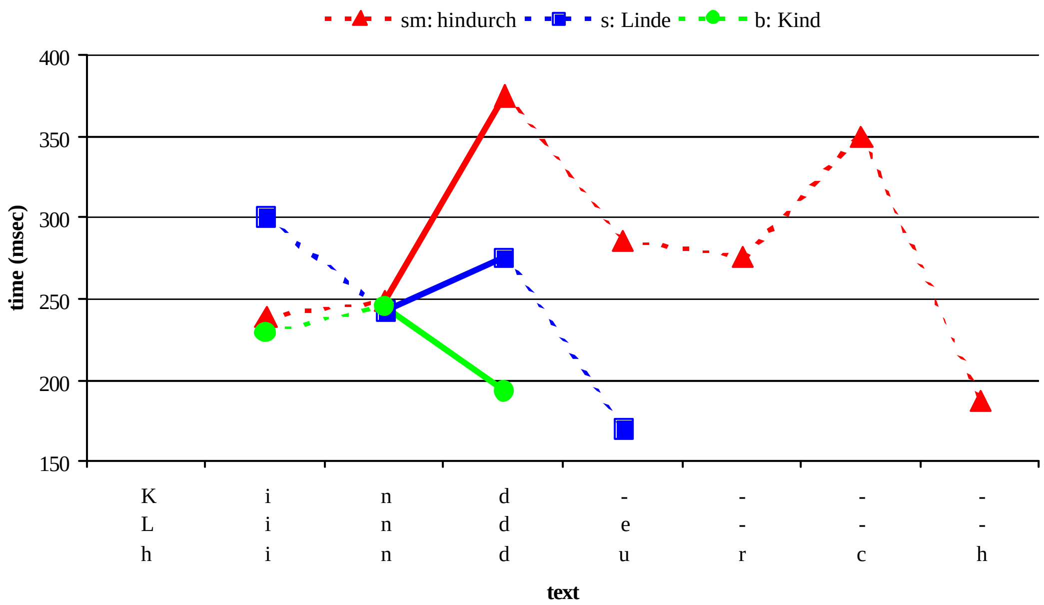


Figure 1: The effects of different within-word boundaries on the string */nd/* (Will et al. submitted).

Will et al. (submitted) conclude that written language production (at word level) takes place according to a certain time pattern: Frame data (e.g. for the structure of a syllable, basic morpheme, word) is provided on various linguistic hierarchical levels over this course of time. The frame data itself does not contain fully specified information of the segments of each respective unit at the beginning of the production, this is provided successively in the course of the production of the unit. The data point to a clear and very stable time course pattern in which the different linguistic structures are produced. It also identifies the points at which the respective information is made available for production from the distribution of frame and consecutive segmental frame filling information. See Will et al. (submitted) for a more in depth discussion.

As Will et al. (submitted) has investigated the linguistic patterns at word level, the logical progression seemed to be to carry this focus onto the next largest unit of language production;

the phrase level. We assumed that the pattern of written language production found at the word level would be mirrored in a macro-structural pattern[3] when it came to participants producing phrases. As the micro-structural within-word boundaries and their effects on the individual words have already been examined, we concentrated on the effects that the different syntactic structures of phrases had on the way in which they were planned and produced.

If one considers the word level findings, and superimposes them onto the phrase level, we assume that the syntactic structure of a phrase is a deciding factor for the time course in which it is produced. Therefore, if two phrases have different syntactic structures they should be produced according to different time courses. In this respect we follow the general assumption in psycholinguistics and computational linguistics that there is a close correlation between the type of syntactic assembly and the processing time required (e.g. Kempen & Harbusch and Piñango in this volume). Figure 2 makes this point clear as it shows two different phrases[4] in the form of their syntactic structures. The *und* phrase, *die zwei und die fünf* (the two and the five), displays a symmetrical structure with the two sub-phrases, *die zwei* and *die fünf,* being joined together by the conjunction *und*. This portrays the meaning that both sub-phrases are of equal standing within the phrase with neither playing the dominant role, i.e. neither *die zwei* nor *die fünf* are the main focus of attention in the phrase. This phrase does not explicitly express any kind of e.g. spatial relation between the referents of the sub-phrases.

The *auf* phrase, *die zwei auf der fünf* (the two on the five), on the other hand, explicitly expresses a spatial relationship. This correlates with a different syntactic structure, which puts emphasis on the first sub-phrase being the dominant one. As can be seen in figure 2 the sub-phrase *die zwei* is the same as in the *und* phrase but, in this case, the sub-phrase dominates the whole phrase. The emphasis is on the position of the first phrase in relation to the second phrase.

Another factor, that differs between the two phrases and could perhaps play a role in the production process, is the grammatical case of the second sub-phrase. With the second *und* sub-phrase being nominative in case and *auf* being dative we suggest that, as a result, different planning and production processes occur which are then reflected in the time course in which the phrases are written. From a psycholinguistic point of view it can be assumed that the nominative case is possibly the default case, whereas other cases require an additional cognitive effort, resulting in increased delays at some point in the production process.

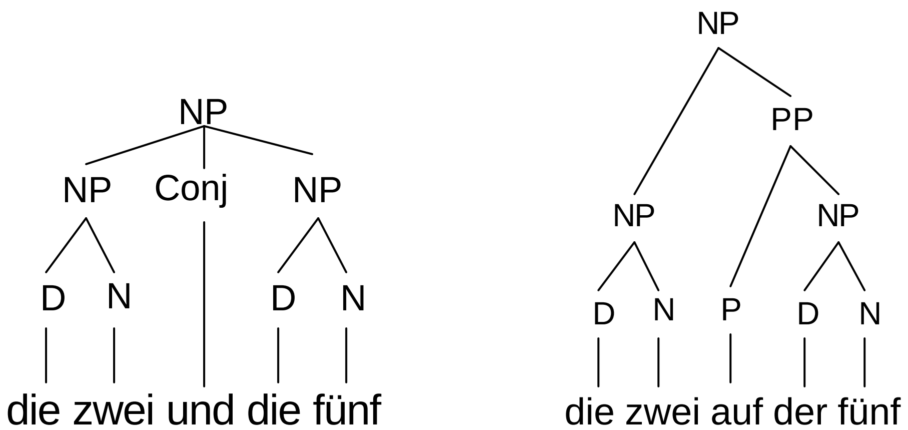


Figure 2: The different syntactic structures of two of the phrases used in the experiment

In recent linguistic literature there has been some discussion on the structure of coordination (e.g. Munn (2000) and Johannessen (1996)), especially regarding the question of whether the sub-phrases really have a symmetrical relation. We do not want to interfere in the intricacies of this discussion, as the differences of the investigated structures, regarding syntactic structure, case marking and semantic relation is in most points undisputed. Perhaps our experimental data can give some hints on the adequate type of linguistic modelling.

We deliberately chose phrase pairs with minimal differences due to the fact that typing is influenced and affected by a number of factors, as mentioned previously. We assumed that, if the factors play a role at word level, they must also play a role at phrase level. We also assumed that the time course of written phrase production is influenced by conceptual processes that go beyond the structure of the phrase itself and depend on the contextual conditions under which the phrase has to be produced. As the *auf* phrase explicitly expresses a spatial relation, it should follow that it will be affected and influenced more by an experimental condition in which a decision between an *auf* and *neben* (next to) phrase has to be made than when the *und* phrase decision process occurs. This is the case because *und* is more neutral with respect to spatial relation. Under this condition the *auf* phrase has to be produced on the basis of a larger search space than under a condition where it has only to be decided whether *auf* or *und* is correct. This additional conceptual process should not affect the production of the *und* phrase.

In our experiment we wanted to test the effects different syntactic structures have on the way in which written phrases of German are produced. In Block A participants had to produce either *auf* or *und* phrases. In block B we included two extra phrase types, *neben* and *unter* (next to and below). These were of the same syntactic structure as the *auf* phrase and were chosen to create extra-conceptual processes (a larger search space, explicit spatial relation and members of the same dative class). This enabled us to test whether the planning and production of the *auf* phrase would be carried out differently in block B than in block A.

Experimental hypotheses

1. The time course of written phrase production is determined by the syntactic structure of the phrase.

For the experiment we tried to find pictorial stimuli with very little semantic interference. We therefore decided to let the participants view the stimuli showing two dice in a number of orientations and then ask them to produce phrases (the phrases to be constructed were given prior to the experiment) that describe the dice relationship.

The influence of the syntactic structures should be seen in the time courses in which the phrases were constructed. If the *und* phrase is constructed as consisting of two symmetrical sub-phrases this should, in comparison with the *auf* phrase, result in a decreased delay at the beginning of sub-phrase one and an increased delay at the beginning of sub-phrase two. Vice versa in the case of the *auf* phrase we expect that it will be produced more as a whole, leading to an increased delay at the beginning of the whole phrase. The sub-phrase two would benefit from this pre-planning, resulting in a decreased delay at its start, compared to the *und* phrase. At some point in the phrase production the dative construction should result in an increased processing time.

If the frame and filler hypothesis from word level can be expanded and used as a guide for the phrase level structures we could say that the phrase and its syntactic structure build the frame and sub-frames with the fillers being made up of the words of the phrase. Therefore, in block A of the experiment we expected the *auf* phrase to display a writing structure that was similar, but different, to that of the *und* phrase with differences being seen in the phrase initial latencies, word initial latencies and total writing times of the phrases.

2. Additional conceptual processes can also influence the time course.

Block B, on the other hand, was made up of four phrase types: *und* and *auf* phrases (as block A) as well as *neben* and *unter* phrases. These extra phrases were included to expand the search space for spatial expressions and effectively create extra-conceptual processes. The extra-conceptual processes were thought to interfere only with the production processes of the *auf* phrase. This meant that any planning that made use of this search space called for the participant to undertake an extra task of selecting the correct phrase from among the three phrase possibilities (*auf*, *neben* and *unter*).

Our hypothesis states that an *auf* phrase in the block containing extra-conceptual processes would be produced significantly slower, than an *auf* phrase in the block free from these extra-conceptual processes. It is also our hypothesis that, in block B, the *auf* phrases will be produced significantly slower than the *und* phrases of block B. The *und* case should display no differences in time structure in either block due to the fact that it is not affected by any extra-conceptual processes.

3. Conceptual processes determine the stimulus reception phase as well as the time course of written phrase production.

Our use of the eye-tracker enabled us to access data that would strengthen the keyboard data found and point to where and when the differences in the planning and production of the phrases take place. We were able to observe the duration and number of fixations and the average size of the pupil during the experimental trials.

We expected that the eye movement data would reflect the fact that, in the block free from extra-conceptual processes, neither of the phrases were produced in a significantly different way. On the contrary, the block containing the extra-conceptual processes would contain a number of significant differences in eye movement as well as keyboard data, when compared to the extra-conceptual process free block, the first occurring during the reception phase. We expected the *auf* phrase to be fixated significantly longer in block B than in block A because of the fact that there were more phrases with the spatial orientation to choose from and so a more intensive examination of the stimuli was needed. This would also manifest itself in the form of a longer phrase initial latency, to be found in the keyboard data. We also expected that during the reception phase there would be significantly more saccades and fixations during the presentation of the *auf* stimuli in block B when compared to block A.

Method

Participants

Fifteen students (7 female and 8 male) aged between 21 and 30 years, studying in the Linguistics Department at the University of Osnabrück, participated in the (first) experiment in return for course credit or payment. Due to technical problems one participant’s data were lost, hence the analyses are based on the results from fourteen participants. In experiment two, eight students (2 female and 6 male) aged between 21 and 40 years, studying at the University of Osnabrück, took part.

In both experiments, the participants were native speakers of German and all had normal, or corrected to normal, vision. All participants were naive with respect to the purpose of the experiment and all had normal typing skills.

Apparatus

The experiment was controlled by a computer, which recorded the data and controlled the presentation of the stimuli by another computer. The stimuli themselves were (800 x 600) bitmaps presented on a 19-inch monitor by the second computer. This resulted in the stimuli occupying the full screen.

The eye movement data were recorded using an SMI EyeLink Hi-speed 2D eye tracking system. The eye tracker data collection rate was 250 MHz, which meant that the position of the participant's eyes and head were sampled every four milliseconds using infrared high-speed cameras. The accuracy of the spatial resolution measurement was 0.01° with the gaze position accuracy lying between 0.5° and 1.0°. Also measured by the eye tracker were the changes in the size of the participants' pupil during the experiment. The accuracy of this measurement allowed for the detection of changes as small as 0.01mm in the size of the pupil.

Materials

During the training phase the participants were presented with the same conditions and trial sequence as in the actual experiment, but on a smaller scale. The block A training session consisted of 18 phrases: 9 *und* and 9 *auf*. The block B training session, on the other hand, was made up of 36 phrases: 9 *und*, 9 *auf*, 9 *neben* and 9 *unter*. On completion of the training phase the participant began the actual experiment, which was constructed in the following way. In block A 42 phrases (21 *und*, 21 *auf*) were to be completed whilst in the B block 84 phrases (21 *und*, 21 *auf*, 21 *neben*, 21 *unter*) were to be completed. Both blocks followed the experimental sequence outlined in the section entitled "Procedure".

Design

Any differences in the way in which the phrases were typed were analysable using keyboard data that were recorded as the participants typed their answer. This data consisted of the exact time recordings of each keystroke so that the time course details displayed during the writing of the phrases (speed, pauses) could be obtained. Eye movement data were observed and recorded using the highly accurate eye tracker system which allowed us to judge whether differences in writing patterns picked up by the keyboard data where mirrored by eye movement data. Both data types were measured with an accuracy of 4 milliseconds. Our aim was to use the two recording media in order to examine whether there were any differences in the time course of written phrase production and, if so, where these differences occurred within the phrase.

Block A was made up of the phrase types: *und* and *auf*. Examples of the phrases that were to be produced are; *die zwei und die fünf* (the two and the five) and *die zwei auf der fünf* (the two on the five). This block is referred to as being free from "extra-conceptual processes". Block B was made up of the four phrase types: *und* and *auf* (as block A) as well as *neben* and *unter*. Examples of the *neben* and *unter* phrases that were to be produced are: *die zwei neben der fünf* (the two next to the five) and *die zwei unter der fünf* (the two below the five). This therefore leads to more interference in the *auf* condition in block B.

The spatial layouts of the different phrases in each block can be seen in appendix A. Each die was 71 pixels in height and 71 pixels in width and was separated from the second die by a spacing of 142 pixels (2 x 71). This spacing was chosen to ease the process of distinguishing which of the two dice the participant was viewing. According to the conditions of the eye tracking procedure, the dice that were to trigger the *auf* phrases are not in direct contact, as could be expected from the standard lexical meaning of *auf*. Direct contact was not possible, because then they had a common border, which therefore could not be differentiated clearly in the eye tracking data. It was also not possible to let this dice position be named with *über* phrases (above), because the typing data from *über* could not be compared with those of *und*: as they have a different number of syllables and, due to its position on the keyboard, the letter *ü* usually causes an increased delay. As the participants were trained to name this dice position with *auf* phrases and no difficulties or irritations were reported with this task, we assume that our data are not affected by this spatial ordering.

When carrying out the analysis of the *auf* phrase saccadic data, the first of the saccades made was discarded. This was done due to the fact that when the participant viewed an *auf* phrase the position of the fixation point necessitated a saccade before a fixation on the first die could be made. In the *und* phrase stimuli case this saccade was not necessary to fixate the first die.

Procedure

Participants were tested individually in a quiet experimental room in the linguistic department at the University of Osnabrück. The experiment consisted of two blocks (block A and block B) and all participants took part in both blocks. In order to reduce interference from external sources as much as possible, 50% of the participants were shown the stimuli block A first and then the B block and the remaining 50% were shown the stimuli in the reverse order. This was done on an alternating basis.

Trials began with the eye-tracker being fitted to the participant’s head. Before any calibration or validation operations were carried out the participants received a sheet of paper containing instructions and diagrams explaining each of the stimuli in the block they were about to tackle (see appendix A for the diagrams of the stimuli). Next to each diagram was printed the phrase that the participant should produce during the experiment. After reading the instruction sheet the eye-tracker was calibrated and validated and, on completion, the training phase began.

A fixation point appeared in the centre of the screen, which enabled the eye tracker to be calibrated after each trial run. When the participant felt ready to start the trial they then pressed the <space bar>, which made the fixation point disappear. As it remained on the screen until the <space bar> was pressed we could not be sure whether the participant had actually focused on this point or had just pressed the key to advance the experiment. Therefore, after a pause of 1500 milliseconds, a red target point was displayed in the centre of the screen. This allowed for the regulation of the spot where the participant had started viewing the stimuli every time. After a further 1500 milliseconds the target point disappeared and a bitmap showing, in the block A condition, a pair of dice in either an *und* or *auf* orientation would be displayed. The participant then had to decide what phrase was being presented to them and then construct the appropriate written phrase.

The phrase to be constructed always described the relationship between the positioning of the die that appeared on the spot where the red fixation point had been and the second die. In the example displayed in appendix A: *die zwei unter / neben / auf der fünf* (the two below / next to / on the five). In the case of *und*, the upper of the two dice was to be named first and the phrase constructed accordingly. In the appendix A example: *die zwei und die fünf* (the two and the five). This part of the experiment was self-paced, meaning that the participants decided how long they needed to look at the pictures in order to construct the phrase. On typing the first letter of the phrase the recording of the eye movement data ceased. Simultaneously, the picture disappeared, replaced, at the bottom of the screen, by the participants’ own typing. This is in contrast to the visual attention and speech production experiment carried out by van der Meulen (this volume), in which the stimuli remained visible until the trial had ended. When the participant had finished writing the phrase the <Enter> key was to be pressed signalling the conclusion of the trial and initialising the next.

On completion of the first block the participant received the instruction sheet for the remaining block and the same process as outlined above was carried out.

Results

The results can be broken down into two major sections. The first section deals with the results and analyses of the eye movement data gained from the eye tracker, whilst the second presents the results and analyses of the keyboard data. These two sections are chronological in order as the eye movement data records the participants' gaze patterns occurring during the stimuli reception phase, prior to the start of the keyboard data recording. This data gives us a more complete insight into the different processes involved in the planning of the writing task and their time courses. The sub-sections making up the eye movement section are the mean fixation times on die one and die two, and the total number of fixations on die one and die two. The writing data includes the total phrase writing time, the phrase initial latencies (PIL's) and the word initial latencies (WIL's).

In both sections the individual sub-section results pertaining to block A will be presented first followed by those of block B. Finally, the results of the comparison between the *und* phrase in blocks A and B will be presented, together with the *auf* phrase comparison results from the two blocks. No outliers were excluded from the eye movement data analyses but they were excluded from the keyboard data analysis, using the normal convention (twice the standard deviation).

Eye movement data

Fixation time

The total fixation times can be split into two areas; these being time spent fixating die one and the time spent fixating die two. Using an ANOVA to analyse the average fixation times on die one in block A (the die to be named first) we found that, during the *und* phrase, the die was fixated for an average of 456.5 ms compared to 769.6 ms in the *auf* condition. This difference was found to be significant (t (13) = 5.624 p <0.0001). The fixation times of die two were then analysed but they yielded no significant differences, with the average fixation times being 259 ms for *und* and 225.3 ms for *auf* (t (13) = -1.033 p >0.05). As figure 3 makes clear die one is fixated longer in the *auf* phrase and the second die is fixated longer in the *und* phrase.

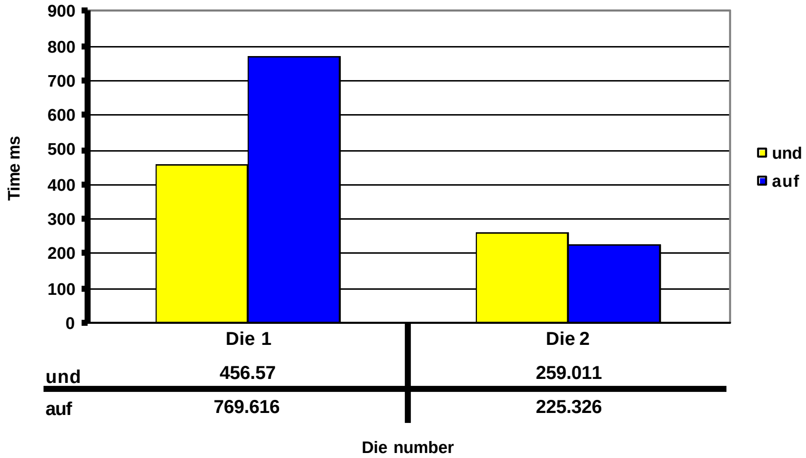


Figure 3: Fixation times on the dice for block A

The eye tracker data from block B were analysed in the same way using the same criteria as outlined for block A. A statistical analysis of the results showed that, in the *und* phrase, the die one mean fixation time was 456.2 ms compared to 799.3 ms for the *auf* phrase. Using an ANOVA we found that this 343.1 ms difference was highly significant (t (13) = 6.175 p <0.0001). Die two was analysed but no significant difference was found in the fixation times (t (13) = 0.129 p >0.5). See figure 4 below.

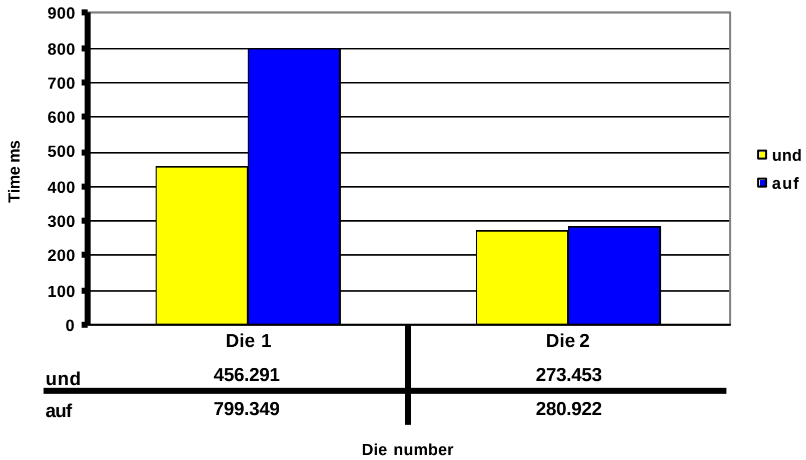


Figure 4: Fixation times on the dice for block B

The final set of analyses compared the eye movement data found in block A, free from extra-conceptual processes, and block B, containing the extra-conceptual processes. The fixation times of die one were analysed and they revealed that, in the *und* phrase type, the difference in fixation times between block A (456.5 ms) and block B (456.2 ms) was negligible and, as a result, not significant (t (13) = 0.009 p >0.5). Die two was then examined and a 14 ms difference in fixation time was found, with the block A fixation time being the shorter. This difference was again too small to create any kind of significant difference (t (13) = -0.329 p >0.5). Moving on to the *auf* phrase, it was found that the mean fixation time of die one in block A was 30 ms longer than that of block B. This difference was not large enough to be significant (t (13) = -0.471 p >0.5). The die two comparison also produced a result that was non-significant, with the mean fixation time in block A being 225 ms whilst in block B it was 280 ms, this difference, as stated previously, was not statistically significant (t (13) = -1.668 p >0.05).

In order to try and get a better idea as to what had caused the significant differences, another experiment, almost identical to the block A procedure from the first experiment, was conducted. The only difference being, that this new block A was constructed with the *und* and *auf* pictorial stimuli in the reverse positions. On analysing the results we found that the mean *auf* fixation time (674.2 ms) for die one was now significantly shorter than that of *und* (885.6 ms) (t (7) = 2.753 p <0.05). The die two results remained non-significant (t (7) = -0.423 p >0.5).

Number of fixations

We then investigated the average number of fixations the participants required for each phrase type. We found that the overall mean number of fixations was 1.5 for die one and 1.1 for die two. A superficial result is therefore that, in general, more fixations were directed towards the first die than the second. It was also found that, in both block A (t (13) = 0.727 p >0.05) and B (t (13) = 0.64 p >0.5), the *und* phrase received fewer fixations on the first die than *auf*. The second die, on the other hand, was fixated more often in block A (t (13) = -0.36 p >0.5) when the participant was dealing with an *und* phrase and more often when portraying an *auf* phrase in block B (t (13) = 0.157 p >0.5). None of the results mentioned were in any way significant.

The mean number of fixation differences between the two blocks was then analysed for the *und* (t (13) = -1.208 p >0.05) and *auf* (t (13) = -0.606 p >0.5) phrases. Both phrase types revealed no significant differences between block A and B in the number of fixations each dice received. A general tendency of both phrase types was that the mean number of fixations was fewer in block A, although, as stated previously, these results were not significant.

The results from experiment two also produced no significant results for die one (t (7) = 0.001 p >0.5) nor for die two (t (7) = -0.42 p >0.5).

Keyboard data

Total writing time

The total writing time of the whole phrase was investigated and, although it revealed that in block A the mean *und* phrase was produced 26 ms quicker than the mean *auf* phrase (6092 ms as compared to 6118 ms), this result was in no way significant (t (13) = 0.296 p >0.5). The block B analysis also showed that the *und* phrase (6179 ms) was written 152 ms faster than the *auf* phrase (6331 ms). This result was not significant (t (13) = 1.463 p >0.05). See figure 5.

When *und* was compared in both blocks it became apparent that, as hypothesised, there was no significant difference in the total writing times (t (13) = -0.415 p >0.05). It was also expected that the extra-conceptual processes in block B would affect *auf* and, as a result, it would be produced in two different writing time structures. On analysing the *auf* data we found that the overall writing time of block A was 213 ms faster than that of block B, although this difference was still not significant (t (13) = -1.141 p >0.05).

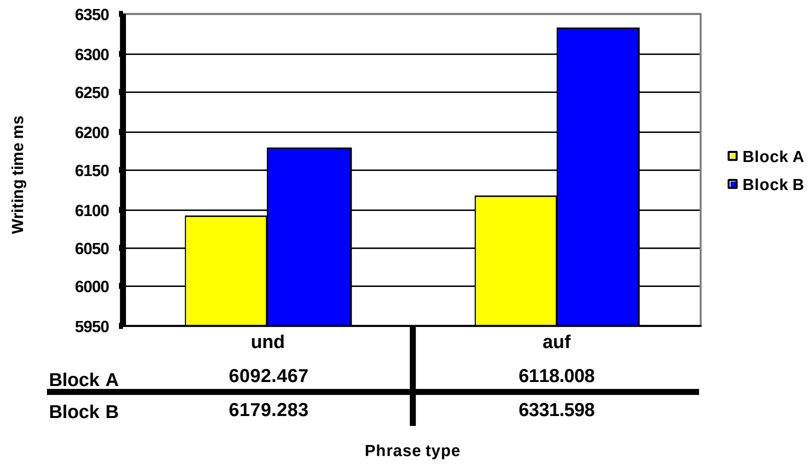


Figure 5: Mean total writing times of the phrases split by block

Phrase initial latency (PIL)

The mean phrase initial latencies (PIL's) for the block A were 1445 ms and 1474 ms for *auf* and *und* respectively. In block B this pattern had, as expected, changed, with the mean PIL's being 1561 ms for *auf* and 1475 ms for *und*.

A paired t-test analysis of the PIL of the two phrases in block A was conducted and the results showed that there were no significant differences in the way they were produced (t (13) = -0.691 p >0.5). The same analysis was carried out on the PIL data from block B. In contrast to block A, it was found that the *auf* PIL was slower, by a level that was tending towards significance, than that of the *und* phrase (t (13) = 1.821 p >0.05). This result was expected due to the presence and effects of the extra-conceptual processes in block B. It also points to the fact that the extra-conceptual processes, and not the pictorial stimuli design, were the most likely cause of this effect, as the stimuli had remained constant whilst the number of conceptual processes, or possible distracters, had increased in block B.

When we compared the *und* and *auf* data from block A with those from block B we found some differences, although none of them significant, between the way the two phrases are written in the two conditions. The PIL results revealed that, as expected, the *und* phrase type displayed no significant difference between the time taken in block A and block B, as block A is only a matter of 2 ms quicker (t (13) = -0.021 p >0.5). In contrast, the *auf* PIL data showed that in the block A condition the PIL is produced 116 ms quicker than its block B counterpart. This difference, although large, was not found to be significant (t (13) = -1.363 p >0.05) and can be clearly seen in figure 6.

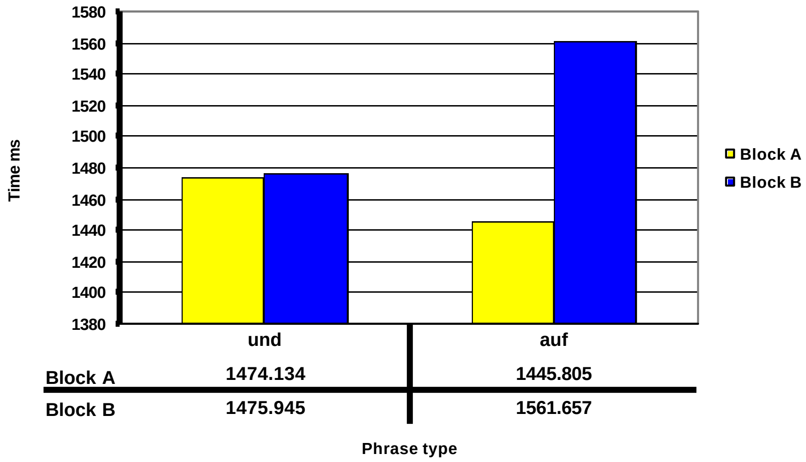
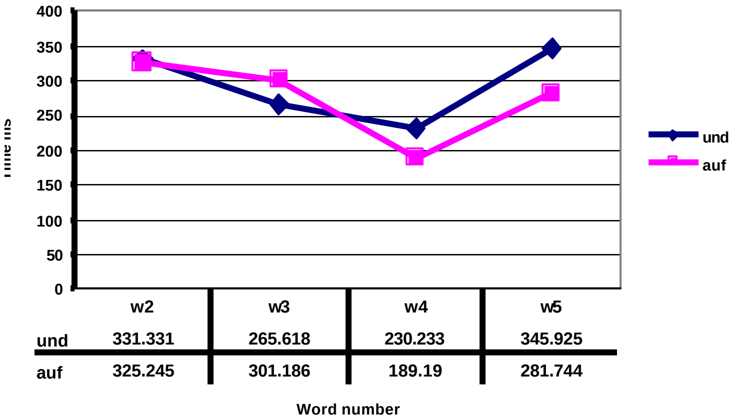


Figure 6: Mean phrase initial latencies

Word initial latency (WIL)

In block A it was found that the mean word initial latencies (excluding the PIL's) were 289.2 ms for *auf* and 298.2 ms for *und*. The block B WIL had sped up slightly in both cases, with *auf* taking 274.3 ms and *und* taking 293.2 ms.

The block A mean WIL's were then examined in detail and it was found that both phrase types produced word two in a similar fashion, with no significant difference (t (13) = -0.596 p >0.5). The production of word three was then analysed, also revealing a non-significant difference (t (13) = 1.223 p >0.05), although the *auf* phrase type was produced 36 ms slower. Significant differences were found during the production of words four (t (13) = -2.269 p <0.05) and five (t (13) = -3.311 p <0.05) with the *auf* phrase type being produced significantly quicker this time (see figure 7). Block B followed the same pattern as that displayed in block A, with the WIL of word two showing no significant difference (t (13) = -0.178 p >0.5). Word three, also, showed no significant differences (t (13) = 1.062 p >0.05), although *auf*, as in block A, was slower. This was followed by a change to the block A pattern, as the significant differences previously found in the production of words four (t (13) = -0.852 p >0.05) and five (t (13) = -2.809 p <0.05) were now only present in word five. Block B did follow the block A pattern only in so far as the *auf* phrase types (with respect to the WIL's of words four and five) remained quicker than the *und* phrases (see figure 8).



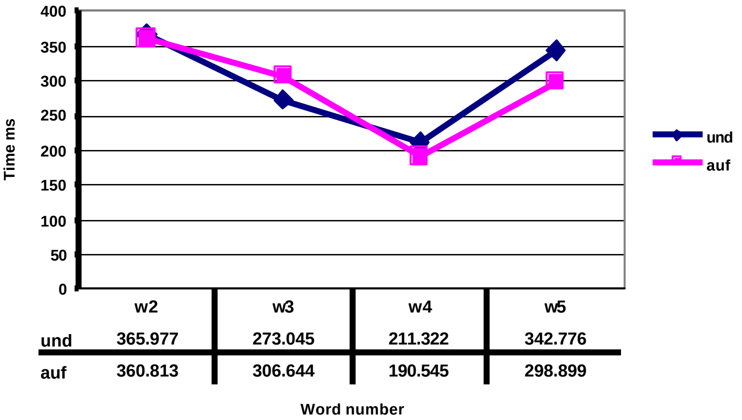
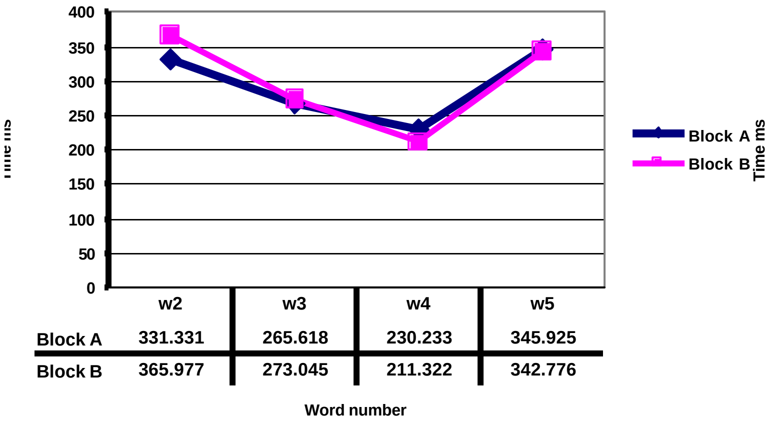


Figure 7: ANOVA results showing the mean word initial latencies for the ***und*** and ***auf*** phrases in block A (w2-w5 = word 2-word5)

Figure 8: ANOVA results showing the mean word initial latencies for the ***und*** and ***auf*** phrases in block B

An ANOVA analysis of the individual WIL's in each block showed that there were no significant differences between the way in which the *und* phrase was produced in block A compared to the way it was produced in block B (see figure 9). *Auf*, too, displayed no significant differences in the way it was produced during both blocks, even though the second WIL in block B was produced 35 ms slower than its block A counterpart (t (13) = -1.438 p >0.05) (see figure 10).



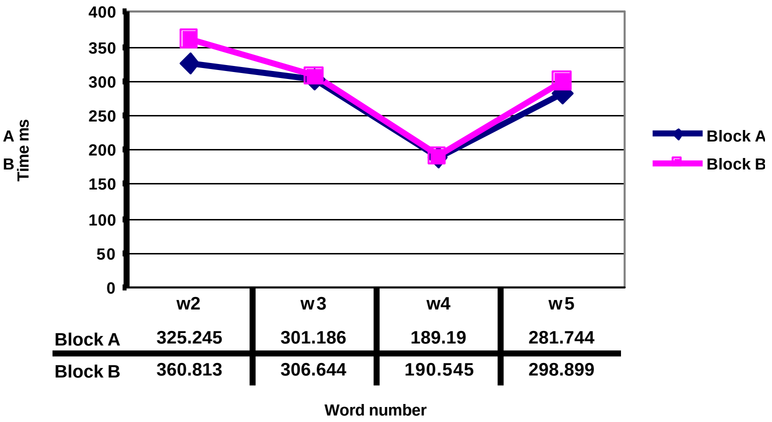


Figure 9: ANOVA results showing the mean word initial latencies for the ***und*** phrase split by block

Figure 10: ANOVA results showing the mean word initial latencies for the ***auf*** phrase split by block

Discussion

Eye movement data

Fixation time

The total fixation times analysed in block A were expected to give us an idea as to whether there was a difference in the way the pictorial stimuli of the phrases were viewed due to the syntactic structures. The fixation times found in block B, when compared with block A, would enable us to see if, and to what extent, the addition of the extra-conceptual processes had an affect on the viewing behaviour of the participants.

The total fixation time of die one in block A revealed that the *und* phrase pictorial stimuli were fixated for a significantly shorter period than those of the *auf* phrase. This initial finding, together with the fact that the second die revealed no significant difference, would suggest that the planning processes taking place during the reception phases are dependent upon the syntactic structure of the phrase.

The block B fixation times revealed the same pattern for both dice; significant differences for die one (*und* shorter) and no significance in the results for die two. The fact that the results display the same time patterns as block A, even with the inclusion of the extra-conceptual phrases, could mean that the overriding factor affecting the reception times is the syntactic structure of the phrase. This was investigated with the comparison of the two blocks and, as expected, the *und* phrase displayed no significant differences in fixation times between the blocks. The *auf* phrase, on the other hand, revealed that the die one fixation time was seemingly unaffected by the extra-conceptual processes as it was fixated in a very similar time course in both blocks. The fixation time of die two, though, showed that the extra-conceptual processes had affected the stimuli reception time, with the block B fixation time being 55 ms longer than that of block A. This result, though not significant, tends to suggest that the slowdown is as a result of the extra-conceptual processes. This lends some weight to our hypothesis that the extra-conceptual processes determine, to some extent, the stimulus reception phase.

Another possible factor that could have influenced the reception times is the design of the pictorial stimuli. We therefore carried out the second experiment in order to better ascertain whether the significant differences found were mainly due to the syntactic differences of the phrases or were caused by the design of the pictorial stimuli. As the two pictorial stimuli now depicted the opposite phrase the results showed that the fixation time of die one in the *auf* phrase was now significantly shorter than that of *und*. This result supports the view that it was the pictorial stimuli design, not the syntactic structure of the phrase, which was the major factor influencing the fixation time behaviour of the participants.

Number of fixations

We expected that, if the fixation times showed some significant differences then, this difference in behaviour would be mirrored in the number of fixations the participants directed towards each of the dice. Unfortunately, no significant differences were found in the data but the results do point towards a loose correlation with the times spent fixating each die.

The correlation can be clarified by the fact that the *und* phrase stimuli received fewer fixations than *auf* in both blocks, probably caused by the design of the pictorial stimuli used in the experiment. The *auf* phrase fixation point was located in the centre of the screen and made it necessary for the participant to make a saccade before being able to fixate the first die to be named. In the case of the *und* phrase, the fixation point was also located in the centre of the screen, but this position corresponded to the centre of the first die to be named, therefore negating the need for a saccade. The correlation is also seen by the way the participants viewed the *auf* stimuli. In block B, the number of fixations on the second die increased, in agreement with the increase in fixation time. This supports our argumentation that, as stated above, the stimulus reception phase is modified due to the presence of the extra-conceptual processes, not only in terms of time but also in terms of the fixation behaviour. As mentioned previously, during the analysis the first saccade taking place in the *auf* phrase was discarded to make up for the differences in behaviour caused by the stimuli design.

The loose correlation results from experiment two, surprisingly, did not reflect that found in the first experiment, as the two phrases received the same number of fixations on die one (1.8 fixations) whilst on die two the *auf* phrase stimuli (1.4 fixations) received slightly more fixations than *und* (1.3). Although, as in the first experiment, the results were all non-significant. This also provides evidence of the influence of the pictorial stimuli on the way the participants viewed the stimuli.

Summary of eye movement findings

In summary, the fixation times for die one in both blocks reveal that the *auf* phrase stimuli are fixated significantly longer, whilst the die two viewing time is similar in both cases. Initially we thought that this would suggest that the planning processes taking place during the reception phases are dependent upon the syntactic structure of the individual phrase, with the *auf* phrase-planning phase being more dependent on the reception time of the first object to be named. If one takes experiment two into consideration, we find that the reception phase is also influenced, to a large extent, by the design of the pictorial stimuli.

The only comparisons that are unaffected by this influence are the inter-block comparisons, as they shared the same stimuli. These comparisons revealed no differences in the fixation times for the *und* phrase, but *auf* showed that the fixation times of die two had increased, although not significantly, by 55 ms in the extra-conceptual process block. This increase in fixation time on die two is mirrored in the (non-significant) increase in the number of fixations found in block B and points to the fact that the extra-conceptual processes had influenced, not just the fixation time, but the fixation number as well.

These data hint at the fact that the context of a task - in this case, contrasting forms of spatial descriptions - may affect the stimulus reception in a specific way, depending on the number of conceptual competitors. This may be due more to conceptual than to syntactic processes.

The negative result of the influence of syntactic structures on the eye movement patterns in the stimulus reception phase may be due to a number of factors. First, our methodology may not have been fine grained enough to find any differences that were present. Secondly, the syntactic structures we compared in these experiments were quite similar, as opposed to e.g. type coercion versus no coercion (Piñango in this volume) or conjoined clauses versus conjoined NPs (van der Meulen in this volume). As a result of this the syntactic processes in our experiments possibly may have been completed in more local or online way, as the keyboard data showed.

Keyboard data

Total writing time

As expected, the phrase writing times in block A displayed no significant differences. With the inclusion of the extra-conceptual processes, in block B, it was expected that the *auf* writing time would be significantly slower than that of *und*, but this turned out not to be the case.

When the results of the blocks were compared with each other, we expected that the extra-conceptual phrases would not affect the *und* phrases, whereas the *auf* phrases would be written in two different time courses. This turned out to be true as the *und* total writing time differed by 87 ms and the *auf* total writing time differed by 213 ms, with the block free from extra-conceptual processes being the faster of the two. These differences, although relatively large, turned out not to be significant. Syntactic structures of the type investigated did not lead to different total writing times, whereas the conceptual differences did.

Phrase initial latency

The mean phrase initial latencies for the block A phrases were found to be remarkably similar. This result is surprising and is contrary to our hypothesis, in which we thought that, due to the different syntactic structures of the phrases, a difference would be found in the way they were written. An explanation for this PIL similarity can be found in the eye tracking data (fixation time) which reveals that a certain amount of syntactic planning (and pictorial stimuli influence) occurs during the stimulus reception.

The PIL of block B exhibited the features that were expected. In the *auf* phrase the PIL was found to be produced in a way (tending towards the level of significance) that was slower than *und*, obviously due to the effects the extra-conceptual processes had on the planning and production of *auf*. When the *und* phrases from the two blocks were compared the difference in PIL was not significant. *Auf*, though, was produced 116 ms slower in block B than in block A. This finding, although not significant, supports our hypothesis that, although the pictorial stimuli and the syntactic structure of the phrases remain constant, the inclusion of extra-conceptual processes plays a role in how the planning and production of a phrase takes place. Whereas the *und* phrase is produced in a similar way in both conditions, the *auf* phrase is produced differently because its search space now contains more phrases, and potential distracters. Therefore, when the participant has decided that the stimulus requires a spatial description, they enter the search space and find that *auf* is not the only option available for selection. This leads to another selection process taking place before the phrase can be produced.

Word initial latency

For the production of word two in block A there appeared to be no difference in the way the two phrase types were written, the differences began to appear from word three. Word three in the *und* phrase was produced 36 ms quicker than the way in which it was produced in the *auf* phrase. Words four and five were also produced differently, this time significantly quicker in the *auf* phrase.

It therefore appears that, when all of the words are analysed and considered together, the different syntactic structures of the phrases affect the time course of written production. The *und* phrase displays a relatively flat time curve, the *auf* phrase, in comparison is reflected in a differently shaped curve. This very general, observation may be interpreted as being a result of a greater load in syntactic planning in the case of the *auf* phrase. Considering the question, of whether the syntactic structure of co-ordinate construction is symmetric or asymmetric, our data do not support the symmetry position. In that case one would expect a larger delay either on word three or four. The rather flat curve of the time course of the co-ordinate construction indicates that a large amount of syntactic planning does not happen at the onset of sub-phrase two. This is more in accordance with the asymmetry position.

The most interesting result concerning block A is the delay on word three and the decreased delays on words four and five, if the word initial latencies of the *auf* phrase are compared with those of the *und* phrase. This indicates a difference in the online syntactic planning of the two phrase types. It can be assumed that, in the case of the *auf* phrase, the decreased delays on words four and five are gained by the slight increase on word three. This may also confirm the assumption that this type of syntactic construction requires more local syntactic planning than the co-ordinate construction, which seems to be produced in a more global way.

The WIL results of block B, initially, mirror those of block A, with no significant differences appearing for word two and a slightly larger, although not significant, difference between the two WIL's of word three, with *und* being the faster of the two phrases. At word four the *auf* phrase begins to be the faster of the two and this continues onto word five. The significance levels of words four and five are also affected, with just word five showing a significant difference.

When the two blocks were compared, the slowdown effect caused by the inclusion of the extra-conceptual processes was found not to create a significant difference in *und*. This points to the fact that the effect of these processes, did not play a telling role in the way the phrase was written. When the *auf* blocks were compared, surprisingly, no significant differences in the WIL's were found. The phrase appears to be written in much the same way with no significant differences.

It can be seen that the extra-conceptual processes affected the template for how the *auf* phrase should be written, especially in the stimulus reception phase, but played a minor role once the phrase type decision had been made. From word three, the normal[5] phrase writing "rhythm" is referred back to. This means that only the PIL and the WIL of word two are modified, or affected, the rest of the template is intact. In this respect this finding is in agreement with our third hypothesis that the conceptual processes determine the stimulus reception phase as well as, at least parts of, the time course of written phrase production.

Summary of keyboard findings

Both blocks displayed very similar writing patterns for each phrase type, with word three being slower and words four and five being significantly quicker in block A and word five being significantly quicker for the *auf* phrase in block B. This suggests that the two phrases in block A, as hypothesised, are written in different ways due to their syntactic structure.

In block B the extra-conceptual processes affect the planning phase, as can be seen by the PIL of the *auf* phrase being produced 116 ms slower than that of block A. Of more interest is the fact that the WIL of word two, as well as the PIL of *auf*, had slowed in block B when compared to block A. This lends weight to our third hypothesis, which states that the stimulus reception phase and writing time course are affected by the inclusion of the extra-conceptual processes. It also points to the fact that when the conceptual processes are present, the planning of the phrase takes place but is not completed during the stimuli reception phase and therefore word two is also affected. The extra-conceptual processes can also be seen to influence the writing time course of *und*, but to a lesser extent, as the writing speed of the *und* phrase of block B is slightly slower than block A.

The results of the inter-block comparison on PIL displayed that the *und* phrases were written in much the same way, whereas the *auf* phrase PIL's of block B were 116 ms slower. This can only be as a result of the influence of the extra-conceptual processes on the phrases due to the fact that the pictorial stimuli and the syntactic structures of the phrases were left unchanged.

General discussion

In experiment one, the fixation times of die one in block A reveal that the two phrase stimuli are looked at in a significantly different way. This significant difference in viewing time of die one is also seen in experiment two, although in this case the reverse fixation time pattern is seen, pointing to the fact that it is the design of the pictorial stimuli used that is playing a major role in influencing the fixation behaviour. When the PIL's of block A from experiment one and those of experiment two are considered this significant difference has disappeared. This means that somewhere during the PIL other processes have taken place, which are also affected by the syntactic structure of the phrases and mean that, in experiment one, the *auf* phrase spends less time completing them than the *und* phrase. In the second experiment, the reverse is the case.

When one looks at the PIL similarity in block A one could be forgiven for believing that the syntactic structure of the phrases had no effect. But, when one considers that the PIL is such a large period of time (mean PIL is approximately 1500ms for block A) it is highly probable that a number of processes, affected in different ways by the syntactic structure, are taking place during this time. When keyboard data alone was used to analyse the PIL any minute differences in behaviour during the PIL time period would go undetected. With our use of the eye tracker we have been able to observe these differences and show that during the stimuli reception phase there are behavioural differences due, not only to the design of the stimuli, but, also, to the syntactic structure of the phrase. This is seen by the significant differences in fixation time on die one in block A. It can be seen that *auf* needs more fixation time on die one, where, perhaps, some phrase planning is completed simultaneously, or, more likely, where the effects of the pictorial stimuli play their role, as seen with the evidence from experiment two. One could argue that this means that the remaining phrase stimuli are then looked at with less planning taking place, as this had already been completed, to a certain extent, during the die one fixation period. On the other hand, *und* doesn't need as much fixation time on die one and this could mean that the planning is more spread out over the whole of the PIL time period or is concentrated in a period of time we have not yet managed to pin-point. As experiment two makes clear, though, it is the influence of the stimuli design that plays the largest role during the fixation time analysis.

This would account for the fact that significant differences were found during part of the stimuli reception period but that the PIL's showed no difference. Block B showed the same fixation time pattern but the PIL also displayed a difference tending towards significance, probably caused by the inclusion of the extra-conceptual processes, as the phrases and the pictorial stimuli had remained the same. These findings support our hypotheses that the conceptual processes determine the stimulus reception phase and that the time course of the written phrase production is determined by the syntactic structure of the phrase.

The WIL data also supports the view that the syntactic structure of the phrase determines the time course of the written phrase production. It has been seen that in both block A and block B the PIL and word two show no significant differences but, in *und*, word three was written in a way tending towards being significantly quicker than *auf*. Words four and five in block A and word five alone in block B, on the other hand, were written in a significantly slower time course in *und*. This could point towards the fact that *und* is written in a very even paced way with the planning distributed over the course of the phrase, whilst *auf* is written according to a different pattern. Words one and two are written in a similar way to the *und* phrase but the word three WIL is slower and seems to include the fore planning for the rest of the phrase to come. This means that the remaining words can be written with less on-line planning (as the planning required has already been done) and are subsequently written in a significantly faster way. In other words, the WIL of *auf* (WIL three) includes the planning processes necessary for the completion of the rest of the phrase whereas in the *und* phrase word three alone is planned.

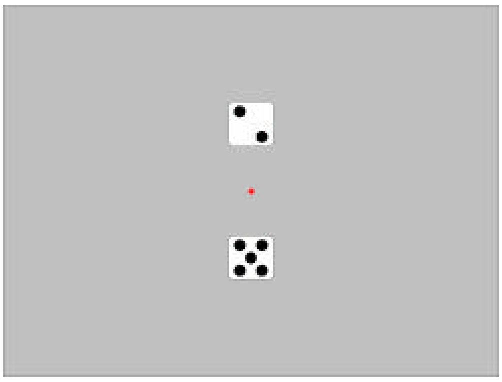
Up to now we must say that the production of syntactic units is a much more distributed process than word production, as can be seen in the time course of written phrase production. In word production we found a very close relation between the time course of production and the linguistic structure of the words. In phrase production there is not such a fixed correlation, though we do find diverse traces of syntactic planning. Several factors may account for this result: Word production is based on stable structures of the mental lexicon, and so it is not very surprising that the words were produced in a very fixed, one might say "optimal", way. Secondly, we found interference of the time course of phrase production caused by syntactic and conceptual processes, whereas this was found to be of less importance for the production of words, once a word has been identified in the lexicon. Thirdly, written language production can rely on the parts of speech already written as an external storage by which the verbal memory is released. This factor does not seem to be of very much importance in word production, but it plays a more important role in the production of phrases, sentences and texts.

According to this assumption word production is optimised with respect to verbal memory and the diverse buffers. Larger linguistic units seem to operate in a less rigid time course, as they always can rely on the words already written. This speculation could be verified by analysing eye movements during the production of written sentences: Reliance on the parts already written, that is reload of the verbal memory, should be observable in eye movement regressions. This could be done in further research.

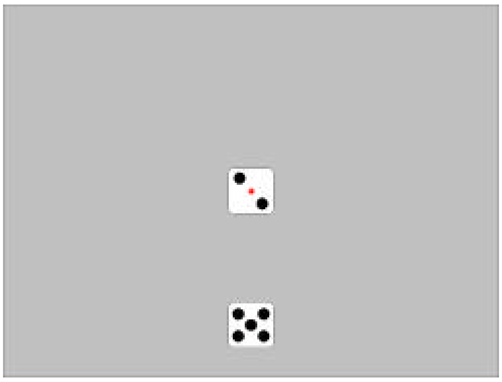
Appendix A

Spatial arrangements of the stimuli in experiment one

Block A (und, auf)

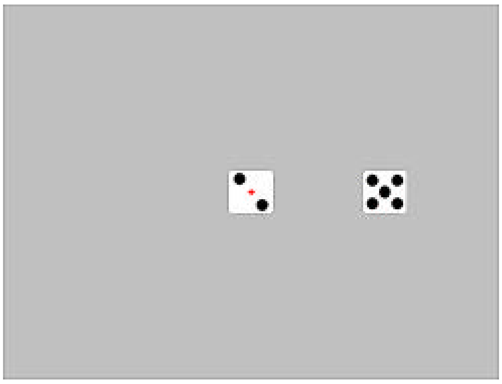


die zwei **und** die fünf
(the two and the five)

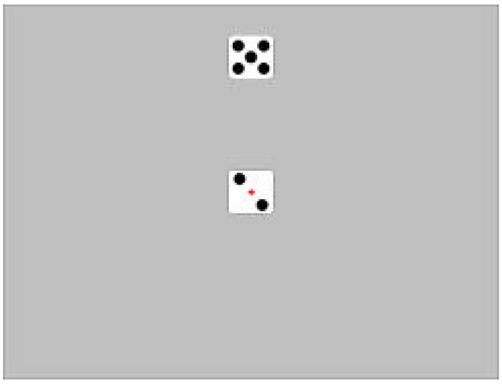


die zwei **auf** der fünf
(the two on the five)

Block B (und, auf, neben, unter)



die zwei **neben** der fünf
(the two next to the five)



die zwei **unter** der fünf
(the two below the five)

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[2] Interkey [time] intervals are the time intervals between successive key-presses and contain information about processes active between key-presses.

[3] Within a word there is a micro-structural pattern of peaks and troughs of IKI times. On the phrase level we are interested in whether or not this structure (pattern) is mirrored over the whole phrase. Hence, macro-structural.

[4] We realise that there are a number of different models put forward that differ with the syntactic structure we used.

[5] The "rhythm" of the phrase free from extra-conceptual processes is meant by the normal phrase "rhythm".