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Why the leash constrains the dog: The impact of semantic associations on sentence production.

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The production of language is one of the most complex and amazing skills in humans. Increasing evidence demonstrated that associative relations (e.g., car - garage) play an important role during concept formation but during speech production the effects and processing of associations are highly debated. Hence, the present study investigated the impact of associations and different SOAs on the production of sentences (Experiment 1) and on naming objects (Experiment 2). In an adapted version of the picture-word interference task, participants were asked to name two pictures using a standardized sentence (e.g., “The car is to the left of the trousers”). Thereby, a simultaneous (SOA = 0 ms) or slightly preceding (SOA = -150 ms) auditory or visual distractor had to be ignored. Distractors were related to the first noun (for example: “The car is to the left to the trousers”, distractor: “garage”) or to the second noun (distractor: “belt”) or unrelated to both nouns (distractor: “bottle ”) of the sentence. At simultaneous presentation, visual and auditory distractors related to the first noun of the sentence prolonged naming responses (i.e., interference). For slightly preceding distractors, only visual presentation induced interference for the first noun of the sentence. During no condition, longer naming responses were found for the second noun of the sentence. These effects suggest that associatively related concepts are active during speech production and can be competitors, i.e., they lead to semantic interference. In Experiment 2, subjects had to name an object (e.g., car) while ignoring a visually presented distractor (e.g., motor). The stimulus set was the same as in Experiment 1. The results showed a facilitation effect if the distractor and the target were associatively related. Overall, the current results provide new insight in the models of speech production: while during single word production, associations facilitate naming, they interfere during sentence production. Hence, associations have an important influence on producing speech but the impact is varied by the context, i.e., single word or sentential.

Key words: picture naming, picture-word interference, sentence production, word association

INTRODUCTION

Although speech production seems to be accomplished without much effort it is nevertheless the result of a complex sequence of processing stages. Most models of speech production assume that fluent language is a product of processes integrating at least two different stages of representation: one stage contains semantic-syntactic properties and the other phonological word form properties (see Levelt 2001 for a review). Firstly, a preverbal message has to be constructed. To this end, during conceptual preparation lexical concepts are activated and selected according to the communicative intention of the speaker (Levelt 1989). An important feature of the lexical network is that there are links between concepts which enable the spread of activation between semantically related concepts (e.g., cat and dog; Indefrey and Levelt 2004). For example, if a picture of a cat is presented, not only the concept “cat“ will be activated but also concepts such as ”animal“ or ”dog“. During lexical selection the corresponding lemma is retrieved from the mental lexicon and its syn-

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tax becomes available for further grammatical encoding, i.e. the appropriate syntactic environment for the word is created (lemma level). If multiple concepts are activated multiple lemmas will get co-activated because each concept is linked to a unique lemma. Thus, the selection of the target lemma depends on the activation of alternatives. Secondly, phonological encoding at the subsequent lexeme level comprises the retrieval of the morphological and phonological properties of the selected lexical items. Finally, prior to articulation the articulatory gestures corresponding to the phonological shape of the utterance are retrieved.

A technique commonly applied to investigate word production processes is the picture-word interference (PWI) paradigm. Here, the participant has to name a target picture while ignoring a visually or auditorily presented distractor word. If the distractor is semantically related to the target (e.g., dog and cat), the semantic interference (SI) effect occurs, i.e. the picture naming latency is slowed down compared to when distractor and target are unrelated (e.g., dog and umbrella; Glaser and Dungelhoff 1984). The SI effect is mainly explained by the hypothesis of competitive lexical selection (Roelofs 1992). This theory assumes that not only one (e.g., cat) but many related candidates (e.g., dog, horse, mouse) are activated by the conceptual information simultaneously, resulting in a competition between representations activated *via* input from a preverbal stage of message processing (Alario et al. 2000). The kind of representations that is involved in this competition is still a matter of debate. Some authors assume that representations at the level of lexical concept processing (i.e., lemmas) are involved (Dell 1986, Roelofs 1997, Levelt 1999, Jescheniak et al. 2001), others consider the phonological level (including word form representations) as its origin (see Starreveld and Heij 1996). In contrast, Mahon and coworkers (2007) suggested that the SI reflects the speed with which production ready representations can be excluded as potential response to the target picture (response exclusion hypothesis), i.e. according to this hypothesis the SI effect arises at a postlexical level of processing and after lexical selection, respectively.

Beside this debate there is another question: Is lexical competition limited to situations where the naming response and the distractor are items from the same superordinate category (for example, furniture with members like couch, bed etc.), i.e. share categorical and/ or semantic relation (e.g., car – bus, dog – cat)? These word-pairs refer to an overlap in features or meaning of words, share similar perceptual or functional properties and are represented in conceptual hierarchies or taxonomies (Tyler et al. 2000, Devlin et al. 2002, Grossman et al. 2002, Hantsch, et al. 2005). But theoretically, due to the spread of activation at the conceptual level and conceptual processing, not only categorical but also associative relations (e.g., car – garage, dog – leash) should be activated.

Semantic associations are initially mediated by complex conceptual relations. Through frequent co-occurrence in language, a direct association between these lexical items is established (Levelt 1989). Hence, associations are “external or complementary relations among objects, events, people and other entities that co-occur or interact together in space and time” (Lin and Murphy 2001). Thereby, they do not share perceptual features and have no functional similarity but rather share a functional relationship (Lin and Murphy 2001). In previous studies, no effect or facilitation was found for semantic associations in a PWI task (Lupker 1979, Schriefers et al. 1990, Heij and Hof 1995, Alario et al. 2000, Sailor et al. 2009). For example, Lupker (1979) presented categorically related (e.g., mouse – dog), associatively related (e.g., mouse – cheese) and unrelated words (e.g., mouse – hand) using a PWI task. He found interference for the categorically related words assuming that only these relations lead to a delay in object naming. Other studies found facilitation for semantic associations, i.e. participants responded faster if distractor and target are related (Alario et al. 2000). The assumed cause is that by presenting an object associated concepts get “co-activated” leading to an advantage of naming the presented objects (e.g., faster reaction times; Alario et al. 2000). Nevertheless, the only study reporting an interference (Abdel Rahman and Melinger 2007) suggested that associatively related concepts are activated during speech at the conceptual level and function as competitors at the lemma level. The critical factor for associative interference is the lexical activation of a common semantic cohort by binding associations through an explicit semantic context that serves as “interface” for co-activations of items (e.g., bee, honey, bee-keeper, comb, honey extractor). In other words, if associatively related words are presented isolated without any semantic context, no interference is induced.

With respect to sentence and phrase production the original design of the PWI task had been adapted and extended in various studies (e.g., Meyer 1996, Damian and Martin 1999, Taylor and Burke 2002, Costa et al. 2006). In general, incrementality is assumed for language production, i.e. a synthesis of serial and parallel processing (Levelt 1989). Hence, information is processed from the conceptual to the articulation level in a serial way whereas the different parts of the utterance can be processed in parallel at different levels of representation. For example, the first noun ”cat“ of the phrase ”the cat and the dog“ is processed at the lexeme (phonological) level while ”dog“ is processed on the lemma level. Several studies found that speakers start to articulate without having retrieved the lemma of the second noun phrase, i.e. not all nouns have to be retrieved before articulation starts suggesting an online retrieval during articulation of the first noun (Meyer 1997, Griffin 2001, Costa, et al. 2006). The idea behind this is that if the linguistic demand is enhanced, participants only retrieve the first part of the sentence and do not “bother about later content words” (Levelt and Meyer 2000) to avoid processing overload. Furthermore, Levelt and Meyer (2000) postulate a temporal overlap between articulation of the first with the encoding of the second item, i.e. speakers lexicalize the second element of the sentence while articulating the first part.

The aim of the present study was to examine sentence planning and especially to get insights how semantic and lexical items interact during language production. As most studies concentrated on categorical relations, we wanted to extent existing literature by investigating the influence of semantic associations. Several naming studies (Abdel Rahman and Melinger 2007, Abel et al. 2009) as well as semantic priming studies of our group (Sachs et al. 2008a, b, Kircher, et al. 2009, Sass et al. 2009a, b) have shown that associative relations play an important role. The difficulty of investigating associations is to ensure that associations are investigated rather than categorical relations. Hence, a clear definition must be given. In the current study, associations were defined as externally related items that interact within scenes or events (e.g., car – garage; drawer – bureau; Lin and Murphy 2001). Those associatively related items share no perceptual features, have no functional similarity but have functional/ contextual relationship (Sachs et al. 2008a). The links between associatively related words can be defined as (for example) spatiotemporal (e.g., roof – house), functional (e.g., chalk – blackboard) and/ or causal (e.g., electricity – light bulb) although more than one relation can be defined between objects, i.e. the functional relation between chalk and blackboard is also spatial (Lin and Murphy 2001). *Via* extensive norming we ensured that the stimuli were associatively related. Firstly, for another experiment of ours (Sass et al. 2009a) we made a free association test where subjects had to produce five associates from a given word (e.g., car). The strongest associate was chosen as target (e.g., garage). Secondly, these word-pairs and some new developed were rated by twelve participants according to their interaction in time and space and how they fit together in situations where they appear together. The rating was replicated in different studies to ensure that the stimuli had a strong associative relationship (Sachs et al. 2008a, b, Kircher, et al. 2009, Sass et al. 2009a, b). Finally, the remaining word-pairs were analyzed according to the Database for noun associations for German (Melinger and Weber 2006) to ensure that there were no categorical relations but rather associative relations. Overall, according to our extensive norming, the careful development of the stimuli and the replication of rating results in earlier studies and the current study, we assumed that the presented stimuli share an associative relationship.

Furthermore, we were interested in the effect that stimulus modality exerts on SI. Previous studies used auditorily or visually presented stimuli (e.g., Starreveld and Heij 1996, Schriefers et al. 1990, Alario et al. 2000, Abel et al. 2009) but so far, only two studies systematically compared the effects of uni- and cross-modal processing (Damian and Martin 1999. Hantsch et al. 2009). For example, Damian and Martin (1999) found that distractors presented in different modalities change the pattern of semantic effects. In a time window from SOA=0 ms to 200 ms the SI effect occurs if the distractors were visually presented. In contrast, using auditorily presented distractors the SI effect occurs at earlier SOAs (-200 ms to 0 ms). Although Damian and Martin (1999) showed that there are effects of modality most studies used either visual or auditory stimuli and did not take this effect into account. Here, we wanted to extend the previous results according to sentence production to underline the role of modality on semantic processing.

Moreover, by including two modalities it is also essential to use two stimulus onset asynchronies (SOA). To affect lemma selection during picture naming, the distractor lemma must be activated during the time window of lemma retrieval of the target (175 ms after picture onset; Indefrey and Levelt 2004). Therefore, for written distractors with a peak of lemma activation around 175-250 ms after word presentation, simultaneous presentation should lead to a maximum effect. In contrast, auditory distractors have maximum lemma activation around 325-400 ms leading to a maximum semantic interference effect at negative SOAs of -150 ms (see Indefrey and Levelt 2004 for a detailed discussion). Furthermore, following the considerations of Meyer (1996) "because a strong semantic interference effect had been obtained at this SOA [-150ms] in an earlier experiment (Schriefers et al. 1990)" and because "the semantic interference effect for the second noun might be stronger at later SOA" it seems plausible to include simultaneous and slightly preceding distractor presentation.

In addition, previous sentence production studies might have been confounded by strategic processing because pictures had to be named in the same order (from left to right). In the current study, we included uncertainty about the order in which the objects have to be named by adding a cue that indicates the first noun of the sentence (and could either be the right or left picture). Until now, no study directly investigated the influence of position and therefore, earlier results could have led to controversial results because of this impact. Nevertheless, theoretically there should be no influence of position as we name objects in our every day life from any direction without any problems.

To summarize, with the current design we were able to investigate the influence of semantic associations during sentence production. In addition, we experimentally manipulated the distractor modality to investigate the influence on sentence planning and used different SOAs, as well as step into a more natural setting by varying experimentally the order of naming the pictures. Hence, we adapted the classical PWI task. Participants were instructed to name two pictures using a standardized sentence (e.g., "Das Auto ist links von der Hose" [The car is to the left of the trousers]) while ignoring a visually or auditorily presented distractor. For half of the participants, the distractor appeared simultaneously (SOA=0 ms), otherwise it slightly preceded the target pictures (SOA= -150 ms). In addition, the picture that had to be named first was marked with a direction cue that was located around either the left or the right object. This procedure was chosen to avoid the use of strategies or induce habituation and to provoke a more natural setting.

Moreover, because the results of the sentence production (Experiment 1) revealed unexpected results, we added an additional second experiment investigating the influence of associations on single picture naming.

EXPERIMENT 1

Methods

Participants

40 native German speakers were recruited (22 male, 18 female; M_{age}=30.5 years; SD=9.5). All participants had normal or corrected-to-normal vision and were right-handed according to the Edinburgh Inventory of Handedness (Oldfield 1971). Participants were excluded if they had been diagnosed with a past or present psychiatric, neurological, or medical disease. Half of the participants were tested with a negative SOA of 150 ms, and the other half with an SOA of 0 ms. The two experimental groups were matched for age and sex ($M_{SOA=0}$=29.8 years, SD=8.9; $M_{SOA=150}$=31.3 years, SD=10.2; p=0.62). All participants signed an informed consent form and were paid a fee of 12€ for participation.

Materials

The material consisted of 192 concrete black-and-white-drawings (International Picture Naming Project; http://crl.ucsd.edu/~aszekely/ipnp/), 48 digitally recorded auditory distractors (Acapela HQ TTS Interactive Demo; http://demo.acapela-group.com) with the speech duration between 283-400 ms (M=356.9 ms; SD=27.4 ms) and 48 written visual distractors.

The pictures and the auditory distractors were validated within two pilot experiments. First, 12 participants not participating in the main experiment were asked to name the pictures spontaneously. Only pictures that were uniformly recognized by every participant were selected. Second, auditory distractors were recorded using a high quality text-to-speech-software leading to a very natural speech. A synthesized voice was used because a natural voice is more variable and the amount of 48 different words would have led to inconsistency, for example in loudness, clearness, accent, dialect and speed. Therefore, with this text-to-speech software we were able to control for speed by keeping naturalness and comprehension constant (see also Sass et al. 2009a). To ensure that the words were comprehensible and sounded natural a pre-test was conducted with eight new participants. They were asked to listen to the recorded words and to repeat them aloud. Only words that were understood by every participant were chosen. Additionally, after completion of the main experiment each participant was asked to rate comprehension and naturalness of the voice on a scale from 1 (no comprehension/ artificial) to 5 (understood everything/ very natural). Results showed that participants understood the auditory words well ($M_{comprehension}$=4.85, $SD_{comprehension}$=0.36) and did not recognize that the voice was artificial ($M_{naturalness}$=4.15, $SD_{naturalness}$=0.82). This fact was supported by a direct request after the rating where all participants reported that they did not realize that the voice was artificial.

For the main experiment, the target was constructed by combining two unrelated pictures. Additionally, one of the two target pictures was marked with a direction cue (black border), whereas the border occurred randomly around the left or right picture. The direction cue served as hint which noun had to be named first, i.e. it could be the right or the left picture. Thereby, the cue was balanced across the sessions (50% on the right, 50% on the left).

Apparatus

The stimuli were presented in pseudo-randomized order to avoid that the same targets appear consecutively. Four randomized versions (incl. order of distractor modality presentation) of the experiment were counterbalanced across participants to avoid a systematic effect of conditions. The stimulus presentation was controlled using the Presentation® software package (Version 11.0; Neurobehavioral Systems, http://www.neurobs.com/). Vocal responses were recorded on digital audio files with Adobe Audition (Version 1.5; Adobe Systems Incorporated).

Procedure

The experiment consisted of a training phase and an experimental task phase. In the training part, the participants saw the target pictures together with the correct names printed below the pictures. This technique was used to familiarize the participants with the names for each of the objects. The participants were instructed to memorize the pictures and their names and to use only the names that were provided. Thereafter, the participants were trained to formulate a highly constrained and standardized sentence in response to the target pictures (i.e. ‘The x [car] is

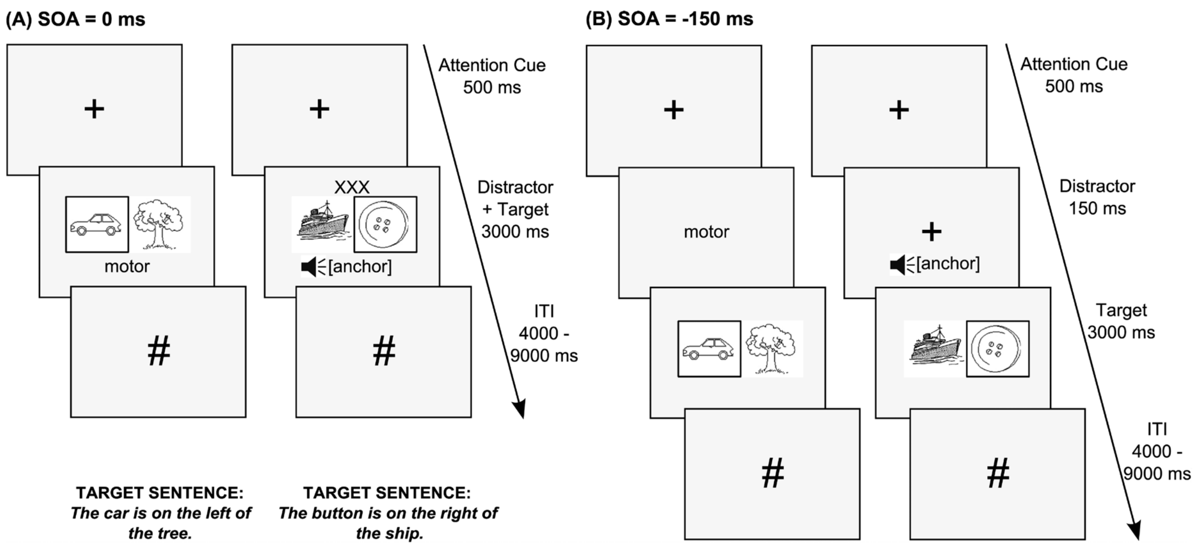

Fig. 1. The picture-word interference task.
After presenting an attention cue, the distractor was (A) presented simultaneously with the target or (B) slightly preceded the target. Last part of the trial was the intertrial interval (ITI). For the auditory condition, the distractor (A) was replaced with a row of X’s or (B) started after a period of 500 ms (attention cue) and ~150 ms before the target was presented.

to the left/ [right] of the y [trousers]'). Then, the main experiment took place. Each trial began with an attention cue "+" (500 ms). Depending on the experimental group, the picture was either presented simultaneously (SOA=0 ms) with the distractor, or the distractor preceded the experimental picture by about 150 ms (SOA= -150 ms). The distractor was either auditorily presented (cross-modal condition) or as a written word (unimodal condition). Cross-modal and unimodal conditions were presented in different sessions but within subjects. After the distractor, the target appeared (3000 ms), followed by a hash mark that was shown for a jittered time range of four to nine seconds (M_{ITI}=6.5 seconds). Participants were instructed to describe the target by producing overtly a sentence with a fixed structure, as practiced in the previous training phase. Sentences had to include (1) the object framed with the direction cue, (2) followed by its positional direction (left / right) and (3) the second object (for example "The car is to the left of the trousers" in case the picture of the car is provided with the direction cue). The participants were instructed to formulate the sentence and name the objects as quickly and as correctly as possible. Naming latencies were recorded with the onset of the experimental picture using a voice key procedure (see Fig. 1 for an example of a trial).

In order to keep the overlap between the distractor presentation and the target onset similar in both distractor modalities at the SOA= -150ms condition, the auditory distractor overlapped with the experimental picture for 200 ms (i.e. its offset was locked to the onset of the target picture), whereas its onset was variable because of the different length of auditory stimuli. For example, the distractor "Papier" (paper) lasted 350 ms. As the distractor overlapped with the target for 200 ms, the distractor started 150 ms before target onset. In contrast, "Tasse" (cup) had duration of 377 ms and started 177 ms before the target was shown. The averaged SOA was -150 ms. The idea behind this is that a variable overlap between words and pictures could lead to differential influences of the distractor on the target. For example, "Papier" (paper) with duration of 350 ms would have an overlap of 200 ms and "Tasse" (cup) an overlap of 227 ms if the onset was locked. As language production is a fast and fluent process, a difference of 27 ms might lead to different processes being addressed.

Conditions

Three experimental conditions were used per modality with two conditions comprising related distractor-target pairs (e.g., car – motor) and one comprising unrelated word-pairs (e.g., car - bottle): (1) 24 distractor words related to the first target name (first noun in the sentence), (2) 24 distractor words related to the second target noun, (3) 48 distractor words unrelated to both targets (see Appendix A for the stimuli list).

The related word-pairs consisted of a distractor and an associatively related target. The associative relation was defined on the basis of "external or complementary relations among objects… that co-occur or interact together in space and time" (Lin and Murphy 2001) and shared either a functional (N = 47; e.g., chalk – blackboard) or a part-whole (N = 49; e.g., bureau – drawer) relationship. The unrelated word-pairs were constructed by rearranging the distractors and the targets in such a way that they are not related to each other. The selection of the items was validated in several separate pilot studies: (1) free association test (Sass et al. 2009a), (2) rating tests where 12 participants were instructed to rate word-pairs from 1 (= unrelated) to 7 (= highly-related) regarding how well the two objects fit together in situations where they appear and interact together, (3) analyses of associations strength (Database of noun associations for German; Melinger and Weber 2006)[1]; $M_{assocfrequency}$=20.76 [range 1-85]). The selected word-pairs (192 out of 250) belonged to the same overall conceptual domain (all words depicted only objects and non-living items, respectively), were concrete and imaginable. They were matched between modalities and noun position according to the direction cue. Distractor and target were matched within modality and within modality and between direction cues (e.g., the unimodal distractors related to the first noun were matched with the unimodal distractors related to the second noun). Furthermore, we matched distractors, targets and distractor-target pairs between modalities and direction cue (e.g., the cross-modally presented stimuli related to the first noun were matched with the unimodally presented stimuli related to the first noun). The criteria for all matches were lexical frequency (CELEX database; Baayen et al. 1993), number of letters, number of sylla-

[1] The Database includes target stimuli and collected associated responses. Our analysis excluded responses from the same category.

Table I

Mean reaction time, standard deviations and percentage errors

	SOA=0 ms				SOA= -150 ms			
Relation	unimodal		cross-modal		unimodal		cross-modal	
	RT (SD)	Error	RT (SD)	Error	RT (SD)	Error	RT (SD)	Error
related to 1st noun	1139.45 (155.90)	17%	1190.31 (158.00)	16%	1158.34 (126.90)	18%	1093.69 (122.30)	14%
related to 2nd noun	1076.70 (163.31)	18%	1157.37 (145.23)	18%	1121.92 (145.75)	12%	1111.42 (141.26)	17%
unrelated	1085.81 (171.33)	16%	1138.89 (137.90)	18%	1112.64 (110.14)	12%	1101.38 (113.05)	13%

Notes: SOA = stimulus onset asynchrony; RT = reaction time in ms; S.D. = standard deviation in ms

bles, and relationship (part-whole vs. functional). The results revealed no differences between pairs ($p>0.10$).

Data analysis

For each participant, the responses were analyzed and the error trials were discarded from further analysis. Three types of responses were categorized as error: (a) incorrect responses, defined as cases where participants did not use the expected picture names or omitted a part of the utterance, (b) verbal dysfluencies (like stuttering, utterance repairs, production of non-verbal sounds that triggered the voice key), and (c) recording failures. The error rates are summarized in Table I. The reaction time for correct responses was measured from the target onset. Raw reaction time data were trimmed by eliminating responses exceeding the mean by more than two standard deviations to reduce skew (Ratcliff 1993; 3.0% of the data). The results of the error analyses are reported only if significant. Trimmed data and errors were entered into a repeated-measures ANOVA by-subject with modality (cross-modal and unimodal) and relation (related to the first, related to the second and unrelated) as within-subject factors and SOA (0 ms and -150 ms) as a between-subjects factor (F^1). In addition, an ANOVA by-item was carried out with SOA as within-item factor (F^2). The location of the direction cue (i.e., whether the first noun was on the left or on the right picture) was taken into account as covariate to attach the variance that might be caused by the picture position of the first noun. To assess the SI effects, paired *t*-tests were conducted comparing the reaction time between related and unrelated trials in every condition separately for each SOA.

Results

The ANOVA of reaction times showed an effect of modality ($F^1_{1,77}=3.90$, $p<0.05$; $F^2_{1,38}=4.37$, $p<0.05$), but there were no effects of SOA ($F^1_{1,77}= 0.29$, $p=0.59$; $F^2_{1,38} = 0.06$, $p=0.82$), and the covariate “direction cue” ($F^1_{1,77}=1.03$, $p=0.31$; $F^2_{1,38}=0.86$, $p=0.36$). The effect for relation was not significant ($F^1_{2,154}=1.86$, $p=0.16$; $F^2_{2,76}=1.18$, $p=0.18$), but the post-hoc Bonferroni correction for multiple comparisons revealed that subjects responded slowest if the distractor was related to the first noun in comparison to the relation to the second noun ([F1]: $M_{post\text{-}hoc}=28.60$, SD=7.85, $p<0.001$; [F2]: $M_{post\text{-}hoc}=28.60$, SD=8.34, $p<0.005$), and the unrelated condition ([F1]: $M_{post\text{-}hoc}=35.77$, SD=7.01, $p<0.001$; [F2]: $M_{post\text{-}hoc}=35.77$, SD=6.47, $p<0.001$). The comparison between the relation to the second noun and the unrelated condition revealed no differences ([F1]: $M_{post\text{-}hoc}=7.17$, SD=6.61, $p=0.85$; [F2]: $M_{post\text{-}hoc}=7.17$, SD=7.01, $p=0.94$). The interaction between modality and SOA was significant in the subject analysis ($F^1_{1,77}=24.58$, $p<0.001$), but not in the analysis by item ($F^2_{1,38}=2.17$,

p=0.15). The same result was obtained for the interaction of relation and SOA ($F^1_{2,154}$=4.26, p<0.05; $F^2_{2,76}$=0.99,p=0.37). The interactions between modality and relation and between modality, relation and SOA did not reach significance (Fs < 1.3). See Table I for mean reaction times and standard deviation.

The differences in reaction times between related and unrelated conditions were taken to calculate the semantic interference effects for the first and second noun. For the SOA=0 ms condition, participants responded slower if the distractor was related to the first noun in comparison the unrelated condition (unimodal: t_{39}=3.63, p<0.01; cross-modal: t_{39}=3.04, p<0.01). The relation to the second noun yielded no difference between the related and the unrelated condition (unimodal: t_{39}= -0.59, p=0.56; cross-modal: t_{39}=1.28, p=0.21). For the SOA= -150 ms condition, the only significant difference was found if the visual distractor was related to the first noun in comparison to the unrelated condition, unimodal 1st noun (t_{39}=3.64, p<0.01; cross-modal 1st noun: t_{39}= -0.55, p=0.58; unimodal 2nd noun: t_{39}=0.77, p=0.45; cross-modal 2nd noun: t_{39}=0.62, p=0.54). See Fig.2 for SI effects.

In general, the error rates were higher in the related conditions in comparison to the unrelated condition providing no evidence for speed-accuracy trade-off and thus are in the line with the reaction time data. An ANOVA conducted on error rates showed a significant effect for relation ($F^1_{2,154}$=3.93, p<0.05; $F^2_{2,154}$=3.93, p<0.05). The significant interaction between relation and SOA ($F^1_{2,154}$=5.34, p<0.01) was not confirmed in the item analysis ($F^2_{2,154}$=0.07, p<0.93). There were no further significant effects or interactions.

Discussion

The aim of Experiment 1 was to investigate the influence of associatively related concepts on sentence production in a unimodal and cross-modal PWI task with two different SOAs. The results revealed that associatively related distractors lead to semantic interference if presented simultaneously with the target picture. This result occurred irrespective of the distractor modality. Hence, interference was only present for the first target noun of a sentence leading to the assumption that not all nouns have to be retrieved before articulation starts.

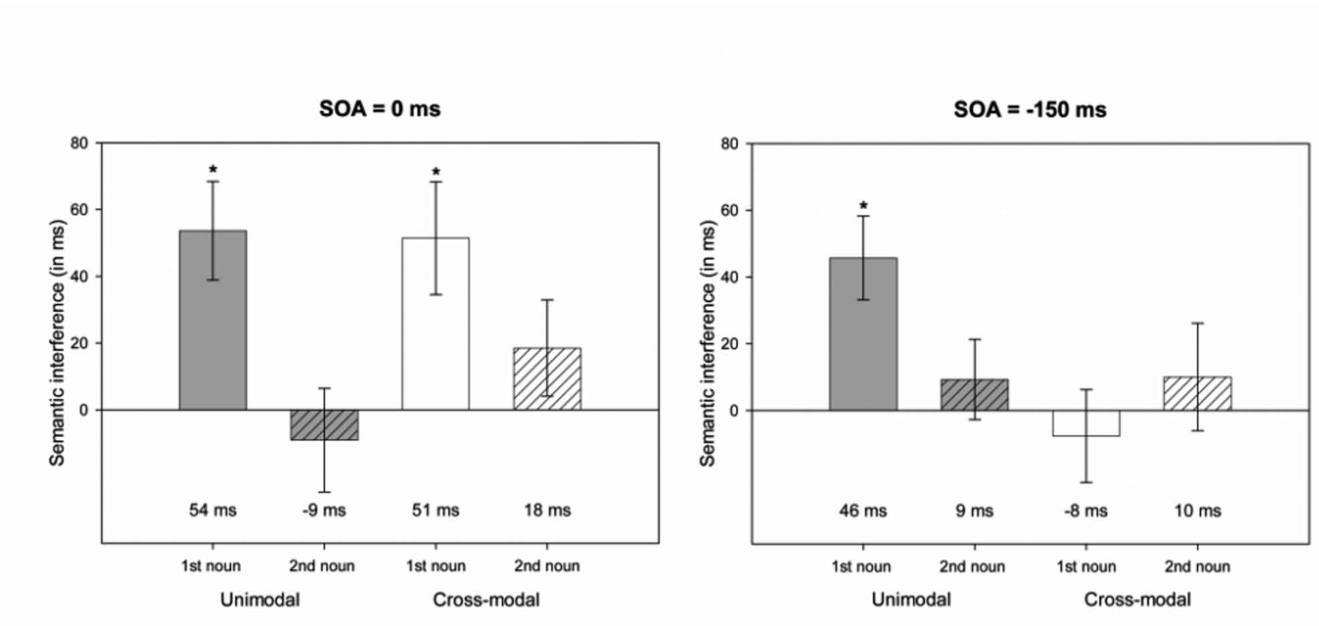

Fig. 2. Semantic interference effect for both SOAs.
The SI effect was calculated by subtracting the unrelated condition from the related condition. For simultaneous presentation (SOA=0 ms), semantic interference was found for visual and auditory distractor related the first noun. In contrast, for the slightly preceding presentation (SOA= –150 ms), semantic interference was only found for the visual presentation of the distractor related to the first noun. Positive values reveal interference (in ms) whereas negative values reveal facilitation (in ms). The labels "Cross-modal" and "Unimodal" refer to the modality condition (auditory and visual distractor, respectively); the labels "1st noun" and "2nd noun" correspond to the position of the noun in the sentence.

Even if Experiment 1 showed that associations are active during speech production the results are somewhat unexpected: In contrast to earlier studies (e.g., Alario et al. 2000, Costa et al. 2005) we found interference rather than facilitation. To ensure that the stimulus set used in Experiment 1 is comparable to recent experiments we conducted a second experiment comprising a classical picture word interference task with single word production.

EXPERIMENT 2

The aim of the second experiment was to investigate the same stimulus set in a classic PWI single word production design in order to test whether the stimulus set evoked the same facilitation effect as in previous single word production experiments (e.g., Alario et al. 2000, Costa et al. 2005, Abdel Rahman and Melinger 2007). If the current experiment reveal facilitation as found by earlier studies, than there must be a significant difference between single word and sentence production, i.e. the sentential context might induce specific mechanisms that change the direction of results for semantic associations.

Methods

Subjects

22 subjects (native speakers of German) who did not participate in Experiment 1 were recruited (10 male, 12 female, M_{age}=29.0 years; SD=2.9 years). All participants had normal or corrected-to-normal vision and were right-handed according to the Edinburgh Inventory of Handedness (Oldfield 1971). Participants were excluded if they had been diagnosed with a past or present psychiatric, neurological, or medical disease. All participants signed an informed consent form and were not paid for participation.

Materials

The material consisted of the same black-and-white drawings (International Picture Naming Project; http://crl.ucsd.edu/~aszekely/ipnp/) that were used in Experiment 1. However, in contrast to Experiment 1, distractors were presented only visually as the effect was most robus during this presentation and the target word consisted only of a single picture.

Apparatus

The stimuli were presented in pseudo-randomized order to avoid that the same targets appear consecutively. Two randomized versions of the experiment were counterbalanced across participants to avoid a systematic effect of conditions. The stimulus presentation was controlled using the Presentation® software package (Version 11.0; Neurobehavioral Systems, http://www.neurobs.com/). Vocal responses were recorded on digital audio files with Adobe Audition (Version 1.5; Adobe Systems Incorporated).

Procedure

Like Experiment 1, Experiment 2 comprised a training phase and an experimental task phase. The training phase did not differ in comparison to the first one except that subjects were trained to name one object instead of producing a standardized sentence. For the experimental part, each trial began with an attention cue "+" (500 ms), followed by the distractor-target presentation (1000 ms). All distractors were presented simultaneously with the target. After the target, a hash mark was shown for a jittered time range of 4000 to 4500 seconds (M_{ITI}=4.25 seconds). Participants were instructed to name the target by producing a single word. Naming latencies were recorded with the onset of the experimental picture using a voice key procedure (see Fig. 3 for an example of a trial).

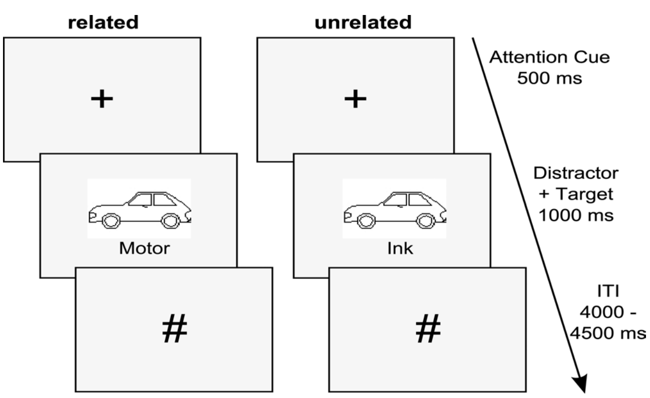

Fig. 3. The single picture naming task of Experiment 2. After presenting an attention cue, the distractor was presented simultaneously with the target, followed by an inter-trial-interval (ITI).

Conditions

Two experimental conditions were used: (1) 96 related distractor target pairs, (2) 96 unrelated distractor target pairs. The stimuli were the same as in the Experiment 1.

Data analysis

For each participant, the responses were analyzed and the error trials were discarded from further analysis (see Experiment 1). The reaction time for correct responses was measured from the target onset. Raw reaction time data were trimmed by eliminating responses exceeding the mean by more than two standard deviations to reduce skew (Ratcliff 1993; 4.0% of the data). Trimmed data and errors were entered into repeated-measures ANOVAs by-subject with relation as within-subject factor. To assess the SI effects, paired t-tests were conducted comparing the reaction time between related and unrelated trials.

Results

The analysis of variance on reaction times revealed an effect of relation ($F^{1}_{1,21}$=18.01, p<0.001), i.e. subjects responded faster if the distractor was related to the picture in comparison to the unrelated condition ($M_{related}$=799.87 ms, $SD_{related}$=71.17 ms; $M_{unrelated}$=836.70 ms, $SD_{unrelated}$=69.83 ms; t_{21}=4.07, p<0.001; see Fig. 4 for results).

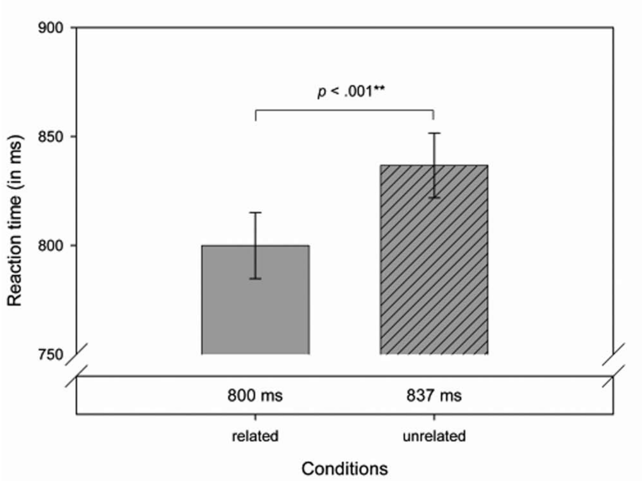

Fig. 4. Semantic facilitation effect for picture naming. During single word production, subjects named the presented target objects faster, if a related distractor was presented.

The analysis on error rates showed no effect for relation ($F^{1}_{1,21}$=0.29, p=0.60; $M_{related}$=4.1%, $SD_{related}$=3.0 %; $M_{unrelated}$=4.3 %, $SD_{unrelated}$=3.3 %).

Discussion

The aim of the second experiment was to investigate the influence of semantic associations on single word production. By using the same stimuli as in Experiment 1, we wanted to ensure that the first results are not based on characteristics of the stimulus set.

In line with existing studies referred to above (e.g., Alario et al. 2000, Costa et al. 2005, Abdel Rahman and Melinger 2007) we found facilitation for associatively related distractors, i.e. subjects responded faster if the distractor and the picture were related in comparison to unrelated distractor-target pairs. This outcome might be related to the spread of activation between related concepts leading to "preactivation" and faster reaction times. Nevertheless, as the results of both experiments differ significantly regarding the direction of effect, differences between single word and sentence production can be assumed. This aspect will now be discussed in more detail in the general discussion.

GENERAL DISCUSSION

The use of semantic associations in sentence production (Experiment 1) and single word production (Experiment 2) revealed two distinct results: While during production of phrases, associations induce an interference effect, they lead to facilitation during single word production. The interference effect is in contrast to previous studies (Alario et al. 2000, Costa et al. 2005, Sailor et al. 2009). For example, Alario and coworkers (2000) compared semantically related (co-ordinate) or associatively related distractor-picture pairs. They observed SI for categorical (Experiment 1) and facilitation for associatively related stimuli (Experiment 2). The assumption was that semantic inhibition and associative facilitation are the result of different processes at different stages of processing, i.e. SI might be caused by lexical selection by competition whereas associative facilitation might be caused by the spread of activation or through the influence of production of word forms (Sailor et al. 2009). In contrast, our results revealed an interference effect if words were associatively related and presented in a frame of a sentence. The discrepancy between our results and the results of other studies could be explained by the number of semantic features and categorical nodes shared between the target and the categorical competitor in comparison to that of the target and its associatively linked competitors (Abdel Rahman and Melinger 2007, 2009). If the target and the distractor belong to the same category (e.g., cat – dog), then the spreading activation overlaps and many competitors are activated simultaneously (e.g., rat, mouse, wolf). Hence, the delay is a result of a one-to-many competition. For associatively related words, the activation does not overlap and therefore, the delay is a result of a one-to-one-competition (e.g., car – garage; Roelofs 1992). Another possible reason might relate to the fact that we investigated the production of complex sentences including different task demands leading to different results, i.e. there might be differences between producing a sentence and naming one picture. As suggested by Levelt and Meyer (2000) the access of words is nearly the same for one or multiple words but differs in some specific points. First, dependency was assumed, i.e. how dependent is the articulation of the first words from any aspects of accessing the second words. Second, temporal alignment was suggested, i.e. parallel vs. incremental access of the words was contrasted. Overall, they found only little evidence for both, dependency and temporal alignment, leading to the conclusion that subjects access the first content word without considering later lexical material. However, producing a sentence includes more than producing single words, for example planning syntactic features. Therefore, further studies are needed to investigate the precise differences between production of sentences and single picture naming.

Abdel Rahman and Melinger (2007) also found associative interference using a semantic blocking paradigm, i.e. they blocked the semantic category (e.g., animals) or the context (e.g., apiary). Interestingly, they did not find an interference effect when associatively related concepts were presented in a classical PWI task (Experiment 3). As we also did not find an interference effect using a classical single picture naming task (Experiment 2), the results highlight the difference between single word and multi word production. Our results and the conclusions drawn by Abdel Rahman and Mehlinger (2007) indicate that interferences for associations can be found if the distractor and the target are presented simultaneously, i.e. categorically as well as associatively related concepts are activated during speech production. Hence, associations lead to interference on the lexical or prelexical level but only if associatively related words are located within a frame of context. This context could be semantic (Abdel Rahman and Melinger 2007) or - like in the current study - sentential. In other words, the occurrence of a word in a sentence differs from the single presentation of a word pair because "a sentence has a meaning distinct from that of individual words comprising it, and it has a syntactic structure that is lacking in single words" (Prior and Bentin 2003). Therefore, sentential context might also have an impact on processing of semantic associations.

Another important difference between the current experiments and the existing literature is the use of a positional statement in the current study. By varying the order of naming the picture, task demands might affect the pattern of results because the participants had to keep track of whether the noun was on the left or right leading to higher attentional demands in comparison to other tasks. By adding the covariate "direction cue" to our analyses we revealed no influence of the position of the first noun on reaction times or error rates, i.e. naming from the left to the right or naming from the right to the left did not influence the participants' responses. Nevertheless, regarding sentence production there might be other processes involved. For example, the activation of a concept leads to activation of related associations. Previously, facilitation was found and assumptions were made based on the priming literature, i.e. the automatic spread of activation leads to pre-activation of related concepts and if such a concept is presented as target it is easier to retrieve it (Neely 1991). Nevertheless, the task structure was always the same: either subjects had to name a picture or they had to name the stimuli from the left to the right (e.g., Meyer 1996, Meyer et al. 1998, Smith and Wheeldon 2004, Costa et al. 2006). Therefore, no one can exclude specific strategies or habituation effects according to the same experimental setting. Offering a new setting and a situation were no standardized left to right reading is required, a more natural and strategy-free situation might be induced. We think that the more natural and complex an utterance the more interference occurs because the simultaneous activation of associated concepts might lead to speech errors or difficulties to chose the correct response. Furthermore, we can not exclude that there are specific memory processes involved because subjects had to remember the position of the first noun. Therefore, differences between our and earlier studies might occur because of different memory systems that were addressed (for example working memory processes because subjects in the most studies were extensively trained before the main experiment started). Third, we did not have a long training phase like the most studies (e.g., Starreveld and Heij 1996, Morsella and Miozzo 2002, Jescheniak, et al. 2003, Meyer et al. 2004, Abdel Rahman and Melinger 2007). The long training phase had the advantage of avoiding mistakes but might lead to experimental and unnatural settings and habituation effects. We showed our pictures only once with the corresponding names because we assumed that the associations will occur irrespective of learning.

With regard to sentence production we found semantic interference only for the first noun. Therefore, we could replicate results of earlier studies that found interference only for the first noun using semantically related distractor-target pairs (Meyer 1997, Griffin 2001, Costa et al. 2006). Hence, the current study revealed that the assumption of incrementality is also true for semantic associations, i.e. not all nouns are retrieved before articulation starts. In addition, by changing the direction of naming randomly (either left-to-right or right-to-left) we induced higher task demands that could also support incrementality (Levelt and Meyer 2000).

We also applied different SOAs and different modalities to influence sentence production. If presented simultaneously, the distractor influenced the first noun irrespective of modality. If the distractor slightly preceded the target, only unimodal (visual) presentation led to a semantic interference. The cause might be the integration of two different modalities because lexical selection takes longer, i.e. a certain time span is required until the word is recognized (Damian and Martin 1999, Indefrey and Levelt 2004). In contrast, unimodal presentation might lead to parallel processing and therefore, the stimuli have a rapid access to their semantic codes (Indefrey and Levelt 2004). Hence, visually presented stimuli lead to SI at a negative SOA or at simultaneous presentation. Here, SI could occur at the prelexical or the lexical level. An auditory distractor needs longer time intervals until being recognized (peak of lemma activation around 325-400 ms; Indefrey and Levelt 2004). Therefore, if SI is linked to lemma selection, one would assume that the negative SOA could lead to greater effects than simultaneous presentation. Another possible influence could be the number of presented items, i.e. for the SOA= -150 ms condition, two target items were presented simultaneously while during SOA=0 ms condition three (unimodal) or four items (cross-modal). The suggestion would be that the processing of two or processing of three to four items at the same time may differ because the number of items per se matters and could enhance task difficulty. Therefore, in a *post-hoc* analysis we compared reaction times within conditions and between SOAs as well as the interaction of SOA and modality independent of condition. The results revealed no significant difference so we assume that there was no influence of item number on processing or speech planning. In addition, as the focus lies on the semantic interference effects (i.e., the difference between the related and the unrelated condition) and as in both relations the same number of items was presented, the influence of items should be the same and is therefore not of interest. Hence, according to our results revealing a greater SI effect for simultaneous presentation, we consider that (1) because auditorily presented stimuli led to interference only when presented simultaneously, no prelexical origin of SI can be assumed. Therefore, (2) the origin of associatively related interference might be at the lexical rather than at the prelexical level. To sum up, according to Abdel Rahman and Melinger (2007) associations might be activated at the conceptual (prelexical) level and are competitors at the lexical level. Nevertheless, the results of the current study could also be explained by the response exclusion hypothesis (Mahon et al. 2007) where semantic (associative) interference arises after lexical selection. Regarding our results this would mean that the unrelated distractor was faster excluded than the related distractor words that fulfill a response criterion demanded by the target (e.g., "name an object"). This assumption is supported by the cross-modal condition. Indefrey and Levelt (2004) assumed that "spoken word distracters require negative SOAs" to affect lemma selection maximally whereas in the current study the strongest effect for associative distractors was found for the simultaneous presentation. Hence, the current study revealed that the origin of associative interference could be located at a lexical or postlexical level. Nevertheless, further studies are needed to clarify and extend this result. In addition, our results showed that visual and auditory-to-visual presentation have different influences on the production of sentences as already suggested by Damian and Martin (1999) and Hantsch and coauthors (2009) and future studies should consider this important impact.

The second experiment used a classical PWI task and revealed an associative facilitation effect in accordance with earlier studies (e.g., Alario et al. 2000, Abdel

Rahman and Melinger 2007). Hence, with these results several important implications can be replicated and underlined. Firstly, associations can lead to facilitation if a classical PWI task with single word production is used (e.g., Alario et al. 2000, Costa et al. 2005, Sailor et al. 2009). Here, the reason might be that there is a automatic spread of activation between related concepts leading to an advantage of naming the target object (Alario et al. 2000). Secondly, there are differences between single word and multi word (i.e. sentence) production. As already pointed out by Prior and Bentin (2003), the production of a sentence includes more than simple naming, e.g. syntactic concepts. Furthermore, the suggestion of Levelt and Meyer (2000) that there are no differences according to dependency and temporal alignment does not exclude the distinction between single word and multi word production. If subjects do not bother about later words of the sentence, they still have to plan the syntactical structure of the sentence. Hence, based on semantic and lexical features of the sentence, there might be no significant differences, while for structural features there are. Thirdly, showing a facilitation effect for our stimulus set in a classical PWI task, we could confirm the results of the main study, i.e. by using the same stimuli in both experiments the results of the sentence production could not be due to the features of the stimulus set as we found the "standard" facilitation effect in single word naming. Finally, with the different results between the classical PWI task and the sentence production task we highlight the influence of context on the production of language. If a context is induced by semantic (Abdel Rahman and Melinger 2007) or sentential features, than associations lead to interference rather than facilitation.

CONCLUSIONS

To conclude, our results showed that semantic associations are activated during speech planning and can be competitors at a specific level that is (post-) lexical rather than prelexical. Furthermore, we propose that a critical factor for associative interference is the context. One possible type of context is the co-activation of many associative concepts (Abdel Rahman and Melinger 2007); the other is the context of a complex noun phrase, i.e. sentence. Contextual factors, however, seem to have an important influence on sentence planning. Therefore, "context" should be included as a factor in future revisions of current models of language production.

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APPENDIX A

Stimuli used in the experiment

Distractor 1 (English translation)	Distractor 2 (English translation)	Unrel (English translation)	Presented objects (English translation)
CROSS-MODAL CONDITION			
Kabel (telephone cable)	Schwamm (sponge)	Lehne (back)	Telefon - Dusche (phone - shower)
Wasser (water)	Decke (tablecloth)	Rüstung (armour)	Seife - Tisch (soap - table)
Tasse (cup)	Fluss (river)	Keller (cellar)	Henkel - Brücke (handle - bridge)
Knauf (knob)	Wolle (wool)	Kuppel (cupola)	Tür - Strumpf (door - stocking)
Paste (paste)	Keller (cellar)	Kamin (fireplace)	Tube - Kiste (tube - box)
Tal (valley)	Tor (goal)	Zirkel (dividers)	Berg - Ball (mountain - ball)
Kuppel (cupola)	Rahmen (frame)	Decke (tablecloth)	Palast - Bild (palace - picture)
Note (note)	Eis (ice)	Absatz (heel)	Flöte - Iglu (flute - igloo)
Kreuzung (cross-roads)	Filter (filter)	Buch (book)	Ampel - Zigarette (traffic light - cigarette)
Falte (pleat)	Suppe (soup)	Fluss (river)	Rock - Kelle (skirt - ladle)
Ziegel (brick)	Papier (paper)	Eis (ice)	Mauer - Schere (wall - scissors)
Eisen (iron)	Schleife (slip knot)	Brunnen (fountain)	Magnet - Geschenk (magnet - present)

Kamin (fireplace)	Gewicht (weight)	Kreuzung (cross-roads)	Schornstein - Waage (chimney - scale)
Stahl (steel)	Brunnen (fountain)	Borste (bristle)	Amboss - Pumpe (anvil - pump)
Ballon (balloon)	Zeiger (clock hand)	Sarg (coffin)	Drache - Uhr (kite - clock)
Figur (chessman)	Saite (string)	Ziegel (brick)	Schach - Banjo (chessboard - banjo)
Buch (book)	Borste (bristle)	Ballon (balloon)	Regal - Bürste (shelf - brush)
Zirkus (circus)	Lehne (back)	Bahn (rail)	Einrad - Stuhl (unicycle - chair)
Dübel (dowel)	Faden (thread)	Paste (paste)	Bohrer - Nadel (borer - needle)
Bahn (rail)	Schal (scarf)	Note (note)	Schranke - Mantel (gate - cloak)
Polster (pillow)	Stufe (step)	Kabel (telephone cable)	Sessel - Treppe (armchair - stairs)
Rüstung (armour)	Boden (ground)	Papier (paper)	Schwert - Teppich (sword - carpet)
Absatz (heel)	Schatz (treasure)	Suppe (soup)	Stiefel - Truhe (boot - chest)
Sarg (coffin)	Zirkel (dividers)	Schal (scarf)	Grab - Lineal (grave - ruler)
Obst (fruit)	Tinte (ink)	Brett (board)	Korb - Füller (basket - stylograph)
Glas (glass)	Pfeil (arrow)	Eimer (bucket)	Lupe - Bogen (magnifier - bow)
Album (album)	Korken (cork)	Wachs (wax)	Foto - Flasche (photo - bottle)
Tempel (temple)	Bügel (hanger)	Bett (bed)	Säule - Bluse (pillar - blouse)
Geld (money)	Eimer (bucket)	Kreuz (cross)	Kasse - Besen (cash point - besom)
Post (post)	Brett (board)	Lampe (lamp)	Umschlag - Säge (envelope - saw)
Anker (anchor)	Kleidung (clothing)	Wand (wall)	Schiff - Knopf (ship - button)
Pedal (pedal)	Wand (wall)	Deckel (lid)	Dreirad - Haken (tricycle - catch)
Zaun (fence)	Kleider (clothes)	Stein (stone)	Tor - Schrank (gate - wardrobe)
Motor (engine)	Axt (ax)	Tinte (ink)	Auto - Baum (car - tree)
Kreide (chalk)	Ruder (rudder)	Pedal (pedal)	Tafel - Boot (blackboard - boat)

Turm (tower)	Drucker (printer)	Motor (engine)	Burg - Zeitung (castle - newspaper)
Gürtel (belt)	Wein (wine)	Knoten (knot)	Schnalle - Traube (buckle - grape)
Taste (keyboard)	Pappe (board)	Thron (throne)	Klavier - Karton (piano - carton)
Schild (buckler)	Bett (bed)	Bügel (hanger)	Säbel - Matratze (saber - mattress)
Vase (vase)	Siegel (seal)	Schild (buckler)	Blume - Brief (flower - letter)
Schiene (rails)	Knoten (knot)	Rasen (lawn)	Zug - Krawatte (train - cravat)
Wagen (auto)	Rasen (lawn)	Gitter (grate)	Reifen - Sense (tire - scythe)
Deckel (lid)	Meer (sea)	Kleidung (clothing)	Topf - Boje (pot - buoy)
Griff (handle)	Kupfer (copper)	Korken (cork)	Tasche - Münze (bag - coin)
Thron (throne)	Lampe (lamp)	Glas (glass)	Krone - Schalter (crown - switch)
Schwelle (sill)	Wachs (wax)	Ruder (rudder)	Haus - Kerze (house - candle)
Stein (stone)	Kreuz (cross)	Zaun (fence)	Schleuder - Kirche (catapult - church)
Schnee (snow)	Gitter (grate)	Siegel (seal)	Schlitten - Sieb (sledge - colander)
UNIMODAL CONDITION			
Maschine (machine)	Mofa (moped)	Leinen (linen)	Fabrik - Helm (factory - helmet)
Etage (floor)	Antenne (antenna)	Stativ (tripod)	Aufzug - TV (elevator - television)
Ständer (stand)	Bikini (bikini)	Farbe (paint)	Schirm - Pool (umbrella - pool)
Spülung (flush)	Vitrine (glass cabinet)	Bommel (pompon)	Toilette - Pokal (toilet - cup)
Kassette (cassette)	Hering (tent peg)	Speiche (spoke)	Radio - Zelt (radio - tent)
Leder (leather)	Bommel (pompon)	Blei (lead)	Peitsche - Mütze (lash - cap)
Leinen (linen)	Blei (lead)	Hering (tent peg)	Sack - Hantel (bag - barbell)
Heu (hey)	Pelz (fur)	Wäsche (laundry)	Gabel - Kragen (fork - collar)
Kugel (cannonball)	Schneide (edge)	Pelz (fur)	Kanone - Messer (cannon - knife)
Sprosse (rung)	Schminke (make-up)	Gepäck (baggage)	Leiter - Spiegel (lad der - mirror)

Stativ (tripod)	Flügel (aerofoil)	Rauch (fume)	Kamera - Flugzeug (camero - airoplane)
Sand (sand)	Band (band)	Filz (felt)	Muschel - Paket (clam - packet)
Gepäck (baggage)	Pfanne (pan)	Schneide (edge)	Koffer - Herd (suitcase - cooker)
Bier (beer)	Lenker (handle bar)	Kaffee (coffee)	Fass - Fahrrad (barrel - bicycle)
Farbe (paint)	Zügel (rein)	Vitrine (glass cabinet)	Pinsel - Sattel (paint brush - saddle)
Kohle (coal)	Wäsche (laundry)	Schminke (make-up)	Ofen - Klammer (oven - peg)
Öffner (can opener)	Speiche (spoke)	Bikini (bikini)	Dose - Rad (can - wheel)
Klinge (razor blade)	Bund (waistband)	Zügel (rein)	Rasierer - Hose (shaver - trousers)
Rinne (cullis)	Mehl (flour)	Lenker (handle bar)	Dach - Mühle (roof - mill)
Rauch (fume)	Hammer (hammer)	Erde (earth)	Zigarre - Nagel (cigar - nail)
Erde (earth)	Seil (rope)	Kassette (cassette)	Hacke - Lasso (hatchet - lasso)
Rost (gridiron)	Kloster (monastery)	Spülung (flush)	Grill - Orgel (grill - organ)
Kaffee (coffee)	Schaufel (shovel)	Sprosse (rung)	Kuchen - Bagger (cake - excavator)
Filz (felt)	Blech (plate)	Mofa (moped)	Hut - Trompete (hat - trumpet)
Porzellan (porcelain)	Schnur (line)	Abfluss (drain)	Teller - Angel (dish - fishing rod)
Spitze (lace)	Keramik (ceramic)	Negativ (negative pattern)	BH - Schüssel (bra - bowl)
Radierer (rubber)	Etui (spectacle case)	Klöppel (clapper)	Bleistift - Brille (pencil - glasses)
Ticket (ticket)	Schraube (screw)	Tastatur (keyboard)	Bus - Mutter (bus - nut)
Tastatur (keyboard)	Park (park)	Stöpsel (stopper)	Computer - Bank (computer - bench)
Gardine (curtain)	Schuh (shoe)	Schlägel (drumstick)	Fenster - Sohle (window - sole)
Orchester (orchestra)	Zünder (fuse)	Zacken (tine)	Geige - Bombe (violin - bomb)
Terrasse (patio)	Zacken (tine)	Kapuze (hood)	Markise - Harke (awning - rake)
Objektiv (lens)	Kapuze (hood)	Schnur (line)	Mikroskop - Jacke (microscope - coat)

Zinken (tine)	Feger (broom)	Riemen (lace)	Kamm - Kehrblech (comb - dustpan)
Anhänger (pendant)	Deo (deodorant)	Porzellan (porcelain)	Kette - Spray (necklace - spray)
Theater (theatre)	Riemen (lace)	Ticket (ticket)	Maske - Sandale (mask - sandal)
Kommode (bureau)	Tabak (tobacco)	Park (park)	Schublade - Pfeife (drawer - pope)
Diamant (diamond)	Mast (flagpole)	Patrone (round)	Ring - Fahne (ring - banner)
Patrone (round)	Stöpsel (stopper)	Mast (flagpole)	Gewehr - Wanne (gun - tub)
Negativ (negative pattern)	Ärmel (sleeve)	Mine (lead)	Film - Pullover (film - pullover)
Schlauch (hose)	Späne (shavings)	Objektiv (lens)	Hydrant - Hobel (hydrant - planer)
Laterne (lantern)	Feder (feather)	Spitze (lace)	Strasse - Kissen (street - pillow)
Tee (tea)	Mine (lead)	Tabak (tobacco)	Kanne - Kuli (can - ball pen)
Klöppel (clapper)	Container (container)	Späne (shavings)	Glocke - Laster (bell - truck)
Schlägel (drumstick)	Geschirr (dishes)	Etui (spectacle case)	Trommel - Spüle (drum - sink)
Altar (altar)	Seide (silk)	Diamant (diamond)	Dom - Hemd (cathedral - chemise)
Abfluss (drain)	Medizin (medicine)	Theater (theatre)	Rohr - Spritze (drainpipe - syringe)
Splitter (shiver)	Schloss (lock)	Geschirr (dishes)	Pinzette - Schlüssel (tweezers - key)

Notes: The structure of target sentence was always the same, for example "*The pencil is to the left/right of the glasses.*" *Presented* objects = experimental pictures that the participants had to describe using the target sentence; Distractor 1 = Distractor related to the first noun; Distractor 2 = Distractor related to the second noun; Unrel = Unrelated distractor to both nouns; the participants saw the objects twice: (1) within the related condition (either related to the first noun or related to the second noun), (2) within the unrelated condition.