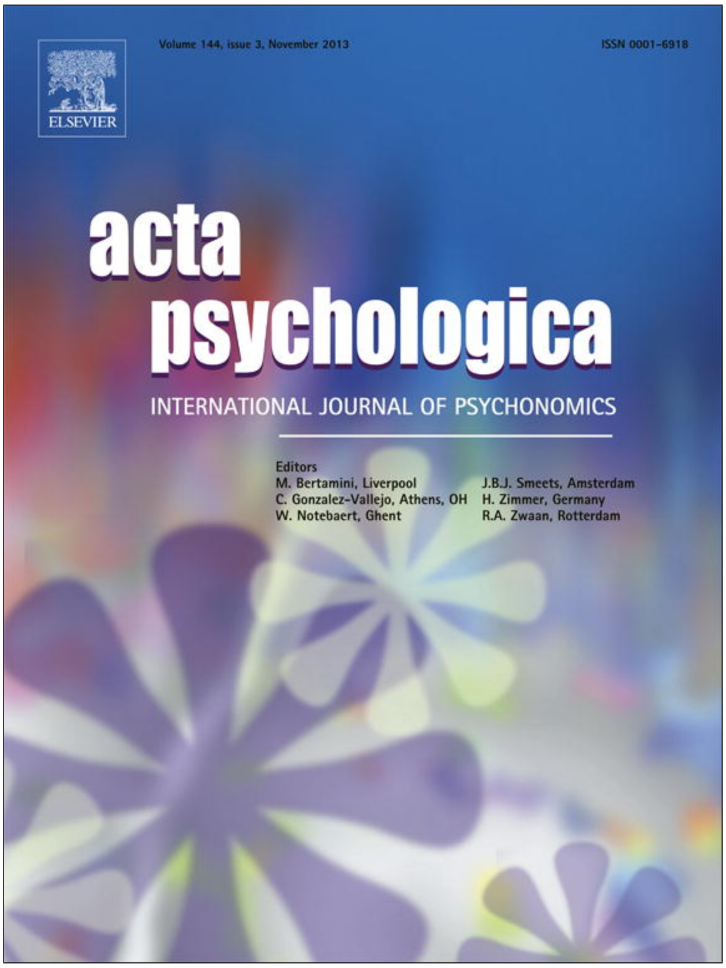
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Semantic interference in language production is due to graded similarity, not response relevance

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ABSTRACT

There is an ongoing debate on the question whether semantic interference effects in language production reflect competitive processes at the level of lexical selection or whether they reflect a post-lexical bottleneck, occupied in particular by response-relevant distractor words. To disentangle item-inherent categorical relatedness and task-related response relevance effects, we combined the picture–word interference task with the conditional naming paradigm in an orthogonal design, varying categorical relatedness and task-related response relevance independent of each other. Participants were instructed to name only objects that are typically seen in or on the water (e.g. canoe) and refrain from naming objects that are typically located outside the water (e.g. bike), and vice versa. Semantic relatedness and the response relevance of superimposed distractor words were manipulated orthogonally. The pattern of results revealed no evidence for response relevance as a major source of semantic interference effects in the PWI paradigm. In contrast, our data demonstrate that semantic similarity beyond categorical relations is critical for interference effects to be observed. Together, these findings provide support for the assumption that lexical selection is competitive and that semantic interference effects in the PWI paradigm reflect this competition.

1. Introduction

Selecting words from the mental lexicon that express an intended message appropriately is a core component of the speech production system. This process involves a spread of activation within and between different levels of speech planning. For instance, upon naming an object, activation spreads to semantically related nodes at the conceptual level where the pre-verbal message is generated. These nodes in turn activate their corresponding entries at the lexical level. As a result of this multi-level spreading activation, the activation of the target word is flanked by concomitant activation of related words. Thus, even for basic and simple instances of speech production such as the naming of visually depicted objects (e.g., chair), semantically related concepts and their lexical entries (e.g., *table*, *wardrobe*) are concurrently activated.

In this paper we explore the consequences of lexical co-activation for word production. We ask whether lexical selection is characterized by competition from co-activated entries or unaffected by the activation status of potential alternatives. Inhibitory effects of semantic contexts on production latencies have long been taken to reflect competition at the level of lexical selection. For instance, when pictures of objects are named in the presence of visually or auditorily presented distractor words in the picture–word interference (PWI) paradigm, a semantic interference effect is observed: naming is slowed in the presence of categorically related relative to unrelated words (e.g., Schriefers, Meyer, & Levelt, 1990). Likewise, repeated naming is slowed in blocks of trials consisting of categorically or associatively related objects (semantically homogeneous blocks) relative to heterogeneous blocks consisting of unrelated objects in the blocking paradigm (e.g. Abdel Rahman & Melinger, 2007; Belke, Meyer, & Damian, 2005; Damian, Vigliocco, & Levelt, 2001; Kroll & Stewart, 1994).

Many models of speech production account for semantic interference effects by assuming that lexical selection is a competitive process (e.g. Bloem & La Heij, 2003; Bloem, van den Boogaard, & La Heij, 2004; La Heij, Kuipers, & Starreveld, 2006; Levelt, Roelofs, & Meyer, 1999; Roelofs, 1992, 2003). For example, according to Levelt and colleagues (e.g. Levelt et al., 1999; Roelofs, 1992) semantic interference effects in the PWI paradigm arise because semantic alternatives are co-activated by the target picture and distractor word at the conceptual and lexical level. Co-activated lexical entries compete with the target for selection, thus delaying the naming response. In contrast, when unrelated words are presented, activation spread by target and distractor word diverges onto different lexical entries, and lexical competition is reduced.

An alternative proposal suggests that lexical selection is non-competitive (Costa, Alario, & Caramazza, 2005; Finkbeiner & Caramazza, 2006a, 2006b; Janssen, Schirm, Mahon, & Caramazza, 2008; Mahon, Costa, Peterson, Vargas, & Caramazza, 2007; Miozzo & Caramazza, 2003). According to the response exclusion hypothesis (REH) by Mahon et al. (2007) semantic interference effects in the PWI task are localized

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at the post-lexical stage of the articulatory output buffer. Distractor words have privileged access to the articulators, and the output buffer forms a bottleneck stage that can be engaged with only one process at a time. Thus, the distractor must be removed from the buffer before the target word can be articulated. The speed of this exclusion process is determined by response relevant criteria. Words that can be quickly dismissed as potentially relevant responses (e.g. unrelated words from different semantic categories) can be excluded faster than words that satisfy response relevant criteria (e.g. semantic category members: when naming a dog the distractor cat fulfills the response relevant criterion of belonging to the same broad category of animals).

Even though the decision mechanism on the response relevance of distractors as such yields discrete results (a distractor is a relevant response or it is not), what counts as a criterion for response relevance is not exclusively determined by semantic category membership. Depending on the goals of the task at hand, different item-inherent or task-related criteria can determine the response relevance of a distractor. This assumption is explicitly formulated in Mahon et al.'s work (2007; p. 512): "There are, in principle an indefinite number of response-relevant criteria, because such criteria are, in part, a product of task constraints decided by the experimenter". Thus, constraints that determine the response relevance of distractors, rather than competitive lexical selection mechanisms, are assumed to be the major source of semantic interference effects.

Evidence in favor of the response exclusion hypothesis stems among others from observed exceptions from classic categorically induced interference effects in the PWI paradigm. For instance, semantically related verb distractors (Mahon et al., 2007), distractors that have a part-whole relation with the target (Costa et al., 2005) and associatively related distractors (Alario, Segui, & Ferrand, 2000; Abdel Rahman & Melinger, 2007; but see Aristei, Melinger, & Abdel Rahman, 2010) induce facilitation, rather than interference. One common element between these types of distractors can be seen in terms of response relevant criteria: given the task at hand (naming whole objects by producing nouns; e.g., target: camel) verb distractors (e.g., ride) can quickly be excluded as potential responses based on their grammatical class membership; likewise, distractors referring to parts of objects (e.g. hump) can be excluded because the implicit task criterion is to name whole objects, and associates (e.g., pyramid) can be excluded because they are not semantic category members. Thus, exclusion times for these types of response irrelevant distractors should be comparable to unrelated words. However, because all of these distractors are semantically related to the target, facilitation due to semantic priming is observed (but see e.g., Roelofs, Piai, & Schriefers, 2012 for a critical review and alternative interpretations of these findings; Abdel Rahman & Melinger, 2009a, 2009b; Kuipers, La Heij, & Costa, 2006; for alternative accounts of semantic facilitation and interference effects that maintain the assumption of lexical competition).

According to the response exclusion hypothesis a semantic priming mechanism at the lexical level is assumed to facilitate naming. In contrast to the discrete response exclusion mechanism responsible for the interference effects, the priming mechanism is graded, varying with the semantic distance between target and distractor. Specifically, given equivalent levels of response relevance, semantically close words (e.g., target: horse, distractor: donkey) are assumed to yield stronger priming effects at the lexical level than more distant words (e.g., target: horse, distractor frog; Mahon et al., 2007). Three experiments run by Mahon et al. (2007) confirmed this hypothesis, although results were not always clear cut. In fact, across the three experiments there are internal discrepancies that were not further discussed by the authors. For instance, semantically close distractors did not always induce interference effects relative to unrelated distractors despite their response relevant status. Furthermore, an SOA manipulation yielded semantic distance effects only at a negative SOA (−160 ms) but not at zero SOA, at which semantic facilitation has been reported for, e.g., part-whole relations (Costa et al., 2005). There is in our view no apparent common element that could explain both supportive and discrepant findings within the study, but these inconsistencies together with no available replication of the effects (see Lee & de Zubicaray, 2010; Vieth, McMahon, & Zubicaray, 2012) invite caution in the interpretation of these results.

Additionally, Mahon et al.'s results contrast with the majority of studies on semantic similarity effects conducted so far, which demonstrated that close relations are associated with stronger interference than more distant relations in semantic blocking and PWI paradigms (Vigliocco, Vinson, Damian, & Levelt, 2002; Vigliocco, Vinson, Lewis, & Garrett, 2004; Lee & de Zubicaray, 2010; Abdel Rahman, Aristei, & Melinger, 2010; see also Aristei et al., 2010).

1.1. Aim of the present study

The discussed examples for different types of distractor words in different experimental settings (see above) suggest that response relevance is not solely determined on the basis of item-inherent features and coarse semantic information, but depends to a large degree also on experimental contexts and task constraints (Mahon et al., 2007). In its current formulations the response exclusion hypothesis does not provide explicit information about the individual contributions of response relevant criteria explicitly defined in task instructions and of those derived from the target stimuli (e.g. categories), nor about the dynamics of their potential interplay. Nonetheless, it is clear in the literature (e.g., Mahon, Garcea, & Navarrete, 2012; Mahon et al., 2007) that explicitly defined and implicitly derived rules are both driving forces of the response exclusion mechanism in terms of response relevance.

In this study we go further in testing response relevance effects in speech production. Until now, relevant semantic item-inherent information was manipulated mainly by means of the selected target categories (e.g., Costa et al., 2005; Mahon et al., 2007), thus, its extraction occurred more implicitly and with dependence on individual response strategies. Here, we investigate response relevance effects by introducing relevant item-inherent semantic information in the task instructions. To do so, we employed the conditional naming paradigm in which picture naming is conditional on a classification of the object as belonging to a pre-specified category (Job & Tenconi, 2002; Mulatti, Lotto, Peressotti, & Job, 2010). For instance, Job and Tenconi (2002) presented a series of living and non-living objects and instructed their participants to name only living things and to withhold the naming response when non-living objects were presented (and vice versa). Interestingly, the authors demonstrated that conditional naming, albeit including an additional semantic classification, is not associated with additional costs compared to unconstrained free naming of all pictures (but see Mulatti et al., 2010). While the specific mechanisms giving rise to this no-cost phenomenon are yet to be fully identified (e.g., Aristei, Abdel Rahman, Sommer, Kiefer, & Job, 2009; Aristei, Kiefer, & Job, 2007), the paradigm is well-suited to explore distractor response relevance.

Here, we combined the conditional naming procedure with the picture–word interference paradigm. Participants were instructed to name only those objects that are typically located in or on the water (e.g., canoe), and to refrain from naming objects that are typically located outside the water (e.g., bike), and vice versa. Object pictures were presented simultaneously with categorically related or unrelated distractor words, that can equally be located in or outside the water (see example below). Thus, by combining conditional naming with the PWI paradigm we can isolate the effects of categorical relatedness and the task-dependent response relevant status of distractor words. For instance, when naming is conditional on the object being typically found in or on the water (e.g. target: "carp"), only items that satisfy this criterion are potentially relevant responses, irrespective of their semantic category membership. For instance, the categorically related distractor *herring* is response relevant (only objects typically located in the water should be named), whereas the categorically related distractor *gecko* is not a potentially relevant response (because geckos are not typically found inside the water). In the unrelated condition the distractor word *pier* is response relevant, whereas *train* is neither related nor response relevant (see Fig. 1 and Appendix).

1.2. Predictions for conditional naming

According to the response exclusion account, all distractors occupy the articulatory output-buffer and must be removed before the target name can be articulated. On a general level, removal is slower for distractors that fulfill response relevant criteria relative to distractors that do not.

A central assumption is that distractor response relevance is based on the affordances of the task at hand and thus, should be substantially affected by task instructions. This assumption is made explicit in Mahon et al.'s work (2007, p. 517): "…a mere change in task instructions can reverse the polarity of the distractor effect from semantic interference to semantic facilitation. In other words, the same materials that produce semantic interference under one set of task instructions produce semantic facilitation under a different set of task instructions."

Accordingly, response relevance here is determined by the instructions for the conditional naming task, and semantic category membership is not diagnostic in terms of response relevance.

Therefore, when participants are instructed to name things that are located in or on the water, related and unrelated distractors that possess this attribute (they are likewise located in or on the water) are response relevant and should delay naming times relative to irrelevant distractors lacking this critical attribute (see Fig. 1). This task-dependent response relevance should be reflected in a slowdown of RTs irrespective of the categorical relation between target and distractor, and should therefore be seen for related as well as for unrelated distractors.

With respect to the effects of categorical relatedness there are two theoretical alternatives. First and most parsimoniously, the explicit task criterion in the conditional naming procedure should override otherwise response relevant item-inherent properties such as category membership. This is because category membership is not a valid and diagnostic criterion for determining relevant and irrelevant responses in the conditional naming task. Thus, only the conditional naming criterion, but not a broad categorical relation, would bear on the response relevant status of distractor words. Furthermore, because any semantic relation to the target is assumed to prime the target lexical entry within equal levels of response relevance (Mahon et al., 2007), we expect purely facilitatory effects for categorically related relative to unrelated words.

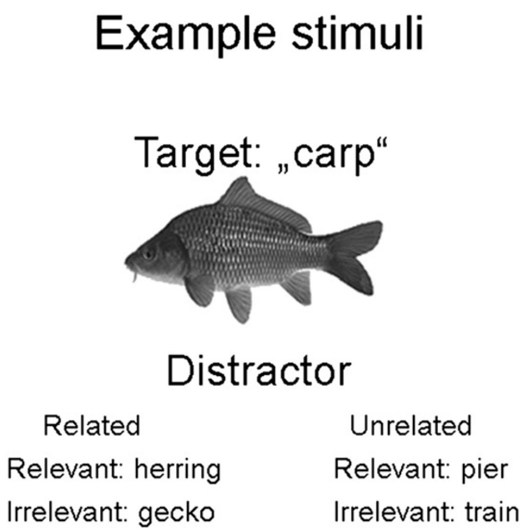

Fig. 1. English example of the four distractor conditions. In this example, the task instruction is to name things that are located in or on the water, and to refrain from naming things typically located outside the water.

Different predictions could be derived if one were to assume that explicit task-relevant constraints cannot override the inherent response relevance of categorically related relative to unrelated distractors. In this case there would be two different types of response relevant criteria, one determining whether to respond or not (the conditional naming criterion), and a second one that has no relation to response decisions and the performance of the specific task at hand (categorical relatedness). However, this idea is in contrast to the description of the response exclusion hypothesis, stating that task instructions are responsible for the reversals of semantic distractor effects (Mahon et al., 2007; but see Kuipers et al., 2006; Kuipers & La Heij, 2008 for an alternative explanation in line with lexical competition).

Alternatively, one might also argue that the conditional naming criterion is applied only to the target pictures and has no influence on distractor response relevance, which depends on categorical relatedness by default. Such a principle is discarded by the REH itself, as it would have fatal consequences for the suitability of the exclusion mechanism. It would in fact imply that the response exclusion mechanism could be fooled by the semantic content of the input, and response relevance as such would be irrelevant.

To bypass this problem, the response exclusion hypothesis assumes that, the decision mechanism is aware of the distractor status of the representation in the buffer (e.g. Mahon et al., 2007, p. 524), and word semantic content specifically relevant to the task is processed and affects the decision mechanism.

Therefore, as described above, the conditional naming criterion, and not semantic category membership, is predicted to determine the time required to exclude words from the output-buffer.

Besides these theoretical arguments against the idea of task-independent response exclusion criteria, we will add a more direct test by including a free naming task described in detail below.

By contrast, according to lexical competition models response relevance should not affect semantic interference effects (but see e.g., Kuipers & La Heij, 2008). Because lexical selection is competitive, categorically related distractors should yield slower RTs than unrelated words. Hence, we expect a classic semantic interference effect, and this should be of comparable magnitude for targets in the response relevant and irrelevant distractor conditions.

1.3. Effects of semantic similarity

Due to the orthogonal manipulation of categorical relatedness and task-related response relevance, the target pictures were necessarily combined with different distractor words in the relevant and irrelevant conditions. Consequently, relevant and irrelevant distractors may differ systematically in their semantic similarity to the target. Because the conditional naming criterion is based on a semantic attribute, response relevant related words (e.g., *herring*) are likely to have a closer semantic relation to the target (e.g., "carp") than response irrelevant related words (e.g., *gecko*), and the same holds for the unrelated condition (e.g., *pier* vs. *train*). This is because response relevant distractors share the semantic feature of being located inside/outside the water, and associated semantic attributes. It has be shown, for instance, that non-categorical relations such as thematic associations (e.g., associates of the thematic context apiary: bee, honey, honeycomb etc.; Abdel Rahman & Melinger, 2007) or even transient formations of ad-hoc categories (e.g., things that may be present on a fishing trip; Abdel Rahman & Melinger, 2011) can also induce semantic interference effects. Likewise, the categories of things that can be found in or outside the water (and associated attributes) may induce such interference effects. Thus, even though we orthogonally manipulated task-related response relevance and categorical relatedness of targets and distractors, we cannot exclude possible differences between response relevant and irrelevant distractors that are due to differences in semantic similarity.

Therefore, to disentangle response relevance and graded semantic similarity beyond categorical relations, we conducted a separate semantic similarity rating with all target and distractor pairs used in the conditional naming task. This rating serves two purposes. First, it should reveal any differences between relevant and irrelevant distractors in terms of semantic similarity. Second, it will be included as a predictor in the statistical analyses, providing further information about the relation between semantic similarity and response relevance and their individual contributions to the effects. To anticipate the results, the ratings showed in fact closer semantic relations between target-distractor pairs in the relevant than in the irrelevant condition.

Furthermore, we included an unconstrained naming task (from now on: free naming) as a control condition (see below).

1.3.1. Predictions for free naming

In the free naming task, all objects were named without restrictions (the typical situation in the majority of picture–word interference experiments). When all pictures should be named, words that are classified as response relevant or irrelevant in the conditional naming task should not induce any differential effects on response latencies in the free naming task. Therefore, for free naming, response exclusion and lexical competition accounts predict the classic pattern of categorical semantic interference effects. Thus, according to the response exclusion hypothesis response relevance effects should emerge only in conditional naming (see above), whereas no such effect should be seen in the free naming task. In contrast, according to lexical competition accounts semantic interference effects should be equivalent in the conditional and free naming task.

Complementing the semantic similarity rating, the free naming task allows us to reveal any differences between the relevance conditions in terms of semantic similarity. As in free naming the response relevance dimension as defined by the conditional naming instruction is not relevant, any differences between the "response relevance" conditions reflect the influence of other factors. Most likely, they can be attributed to differences in semantic similarity, with "relevant" distractors having a closer relation to the target than "irrelevant" distractors.

Importantly, if differences between relevant and irrelevant distractors are due to graded differences in terms of semantic similarity, specific predictions can be derived. In this case we expect comparable latency differences between relevant and irrelevant words in the conditional naming task (where the property inside/outside the water is critical for correct task performance), and in the free naming task (where response relevance is not defined upon the typical location of the object). Thus, together with the semantic similarity rating, free naming enables us to disentangle task-related response relevance and graded semantic similarity.

As to the polarity of semantic similarity effects, the two theoretical approaches predict opposite results. According to the response exclusion hypothesis a semantically close distractor from the same superordinate category should prime the target more than a semantically distant distractor from the same category (e.g., target: horse; distractor: zebra vs. whale; Mahon et al., 2007; see discussion above). Therefore, with the response relevant status being equal (e.g., in the free naming task, within the class of related and within the class of unrelated words), close distractors should facilitate naming compared to distant distractors.

In contrast, according to lexical competition models strongly activated concepts should yield stronger competition, and thus longer naming latencies, than weakly activated distractors (e.g., Aristei et al., 2010; Roelofs, 1992; see also Abdel Rahman & Melinger, 2009a, 2009b). Therefore, semantically close distractors should yield stronger interference effects than distant distractors.

Importantly, for the present purpose, the polarity of graded similarity effects is not the most critical aspect. If any effects are present in both tasks, we can conclude that they reflect differential effects of graded semantic relations between target and distractor, rather than distractor response relevance.

2. Methods

2.1. Participants

23 females and 7 males, aged from 20 to 45 years (mean age = 26.3 years), were paid for their participation in the experiment or received partial fulfillment of a curriculum requirement. All participants were native German speakers and reported normal or corrected-to-normal vision.

2.2. Materials

The target picture set consisted of 100 color photographs of common objects, scaled to 3.5 × 3.5 cm. Half of the objects are typically located in or on the water (e. g. yacht), and the other half are typically located outside the water (e. g. bus). The objects belonged to five semantic categories (animals, plants, clothes, tools, and vehicles). Within each category the objects were equally distributed between the two domains (inside vs. outside the water). The auditory word distractors consisted of 100 object names, recorded with a male voice at a sampling rate of 44 Hz and a sample size of 16 bit. Importantly, the distractor words were not part of the response set (cf. Appendix).

Each object (e. g., yacht) was paired with 4 distractor words which were (a) categorically related and response relevant (e. g., galleon), (b) categorically related and response irrelevant (e. g., carriage), (c) categorically unrelated and response relevant (e. g., swordfish), or (d) categorically unrelated and response irrelevant (e. g., snake; see Fig. 1 for an illustrated example of all distractor conditions). The related words were re-assigned to different pictures for the unrelated condition. Each distractor word appeared in all relatedness and relevance conditions.

2.2.1. Semantic similarity rating

To estimate the graded semantic similarity between targets and distractors in all four experimental conditions, we conducted a semantic similarity rating. Ten participants who did not take part in the experiment were presented with all target name–distractor word pairs and were asked to rate their semantic similarity on a Likert scale from 0 (very dissimilar) to 5 (very similar). The order of the target–distractor pairs was randomized for each participant individually. ANOVAs with the within-subject factors relatedness (categorically related vs. unrelated) and relevance (defined as relevant vs. irrelevant response in the conditional naming task) revealed highly significant effects of relatedness (categorically related distractors were rated as more similar to the target than unrelated distractors, $F1(1,9) = 382.6$, $MSE = .06$, $p < .001$; $F2(1,99) = 910.6$, $MSE = .36$, $p < .001$), response relevance (distractors classified as response relevant in the conditional naming task were rated as more similar to the target than irrelevant distractors, $F1(1,9) = 88.0$, $MSE = .03$, $p < .001$; $F2(1,99) = 69.4$, $MSE = .41$, $p < .001$), and a significant interaction of relatedness and relevance, $F1(1,9) = 27.4$, $MSE = .02$, $p < .005$; $F2(1,99) = 13.5$, $MSE = .35$, $p < .001$. t-Tests confirmed that relevance effects were significant in the related ($t1(9) = 11.1$, $p < .001$; $t2(99) = 6.6$, $p < .001$) and unrelated condition ($t1(9) = 4.3$, $p < .005$; $t2(99) = 6.3$, $p < .001$). These results demonstrate that response relevant distractors have a systematically closer relation to the targets than response irrelevant distractors (see Fig. 2).

2.3. Procedure

Prior to the experiment participants were familiarized with the visual stimuli and their names as follows: First, all photographs were presented in random order on the screen and participants were asked to name each picture and to say whether it was typically located in or

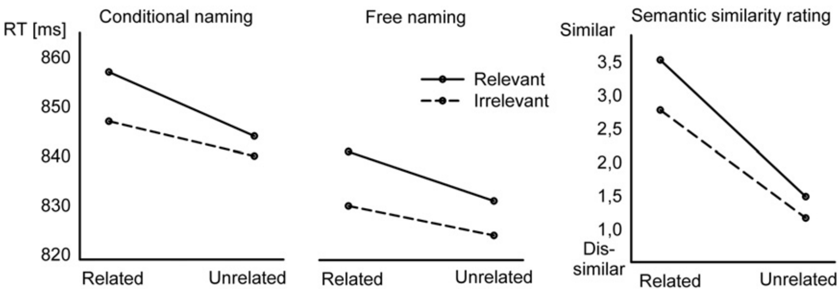

Fig. 2. Effects of distractor relatedness and response relevance in the conditional naming task (left), the free naming task (middle), and the results of the semantic similarity rating (right). Note that the factor response relevance is only applicable in the conditional naming task.

on vs. outside the water. If necessary, they were corrected or the picture name was provided by the experimenter. Then, participants were given printed color sheets with all pictures and their names printed below.

Stimulus presentation and response recording were controlled by Presentation software (Neurobehavioral Systems). Each trial began with a fixation cross displayed in the center of a black screen. After 500 ms the distractor word was presented auditorily, followed by the target picture after 100 ms (SOA: −100 ms). At an SOA of −100 similar semantic interference effects for visual and auditory distractors have been reported (Damian & Martin, 1999). The picture remained on the screen until vocal response, with a maximum duration of 2500 ms. The inter-trial interval (ITI) varied randomly between 900 and 1100 ms.

Vocal responses were recorded with a microphone and naming latencies were measured with a voice key. Naming accuracy and voice key functioning were monitored online by the experimenter. Participants were informed that they would hear a word shortly before the appearance of the picture, and were instructed to ignore it. They were not informed about the potential relation between target and distractor. In the conditional naming task participants were instructed to name only objects that were typically found in or on the water and refrain from naming objects typically found outside the water, and vice versa. In the free naming task participants were instructed to name all objects. They were instructed in both tasks to respond as fast and accurately as possible.

The whole experiment consisted of three task blocks which corresponded to the three naming conditions: Free naming, conditional naming “inside”, and conditional naming “outside” the water (c.f. Introduction section). Within each task block all 100 pictures were presented once with each of the four distractor types (categorically related/unrelated, response relevant/irrelevant). Thus, each picture was presented four times in each task block, and 12 times in the entire experiment. The whole session consisted in 1200 trials. All task blocks were subdivided by short breaks, in which participants could rest with no time restriction. The order of the three task blocks was counterbalanced across participants. The order of picture presentations and distractor conditions within each task block was fully randomized individually for each participant.

Table 1
Mean response times (RTs) and error rates (Err) with standard errors of means (in brackets) for each task and distractor condition.

Distractor	Conditional naming			Free naming		
	Mean RT (ms)	SE	Err rate (%)	Mean RT (ms)	SE	Err rate (%)
Related–relevant	857	16.27	6.33	841	21.59	5.96
Unrelated–relevant	844	15.82	4.62	831	22.42	4.92
Related–irrelevant	847	17.06	5.42	830	22.56	6.20
Unrelated–irrelevant	840	14.45	4.87	824	24.28	6.54

3. Results

Mean response times (RTs) for correct trials, standard error of means, and mean percentages of errors in the experimental conditions are presented in Table 1. Trials with incorrect naming, stuttering, mouth clicks, or vocal hesitations, and trials with voice key failures or malfunctioning were discarded from the RT analysis (across all participants the percentage of naming responses in the no-go condition, i.e., “false alarms”, was 0.69%). Furthermore, trials with RT latencies faster than 330 ms (0.06%; extreme values were identified through graphical detection) were removed from the analysis as well. For conditional naming only go trials were included (i.e., trials in which a response was required).

We analyzed RTs with linear mixed model analyses[1] (lme4 package implemented in R system GNU software; Version 2.10.1, December 2009; Bates, 2005) with participants and items as crossed random factors (Baayen, Davidson, & Bates, 2008). These analyses allow us to disentangle potentially spurious effects (as expected for response relevance confounded with semantic similarity), and to easily include the semantic similarity rating as a continuous predictor. All models included fixed effects and random intercept for participants and items. Given the large number of observations, estimates with t-values larger than 2 are considered significant (Baayen et al., 2008).

Model I included the predictors task (conditional naming vs. free naming), relatedness (categorically related vs. unrelated), relevance (relevant vs. irrelevant), and all interactions.[2] Thus, here we ignore potential differences of semantic similarity between the relevance conditions. This analysis revealed effects of relatedness, relevance and task (β coefficients and t-statistics are summarized in Table 2). Naming latencies were slower for related than for unrelated, as well as for relevant than for irrelevant distractors. Furthermore, naming latencies were slower in the conditional than in the free naming task. However, no interaction reached significance.

Most important for the present purpose, even though we found effects of task and response relevance, their interaction was not predictive for the observed RTs. Thus, although slower naming times associated with response relevant relative to irrelevant distractors were directly predicted by the response exclusion account, this account also predicts an interaction of task with relevance. Relevance should be a strong predictor only for conditional naming, but not for free naming. The observation of “response relevance” effects in the free naming task suggests that these effects might indeed be due to different levels of semantic similarity. Highly significant differences between “relevant and irrelevant” distractors in the semantic similarity rating (cf. Materials section) confirm this idea.

[1] As LMM of log-transformed RTs yielded the same results as LMM of untransformed RTs, we report results for the analyses of untransformed data.

[2] Testing Model I separately for the two tasks revealed response relevance effects of very similar magnitude in free and conditional naming, $\beta = 10.732$, $t = 2.20$ and $\beta = 10.121$, $t = 2{,}23$, respectively.

Table 2
Intercept coefficients and t-values for all predictors included in the reported linear mixed models. Predictors with t-statistics exceeding a value of 2 are considered significant.

	Model I (df = 22,722)		Model II (df = 22,725)		Model III (df = 22,725)	
Predictor	Coeff.	t-Value	Coeff.	t-Value	Coeff.	t-Value
Relatedness	15.758	3.27	−6.143	−1.31	−6.143	−1.31
Relevance	10.980	2.28	2.709	1.01	2.709	1.01
Task	9.993	3.27	13.620	5.67	13.620	5.67
Semantic similarity	–	–	8.839	3.99	6.977	6.27
Relatedness × relevance	5.402	0.79	–	–	–	–
Relatedness × task	5.507	0.81	–	–	–	–
Relevance × task	1.122	0.16	–	–	–	–
Relatedness × relevance × task	1.180	0.12	–	–	–	–

When the semantic similarity rating is included as an additional (continuous) predictor in the model (Model II; see Table 2) the estimates of relatedness and relevance fail to reach significance (since no interaction was significant in the previous model we excluded the relative predictors). In addition, the model revealed high correlations of semantic similarity with relevance ($r = .44$) and relatedness ($r = .86$) estimates. These results strongly suggest that mainly semantic similarity determines interference effects in both tasks, and that differences in semantic similarity can account not only for the effects of categorical relatedness but also for the effects of response relevance observed in the conditional and free naming tasks.

To exclude loss of power as an account for the response relevance (and relatedness) failing to reach significance, we decorrelated relevance and relatedness from semantic similarity by regressing them on semantic similarity and taking the residuals as new predictors. The third model, thus, included the residualized relevance and relatedness, and furthermore, semantic similarity and task as predictors (Model III; Table 2). This model confirmed that relevance and relatedness effects are not significant beyond semantic similarity. In fact, the coefficients were almost identical to the previous model and the correlations were strongly reduced ($rs < 0.2$).

Finally, to confidently claim that response relevance effects are determined by semantic similarity and not vice versa, it is necessary to show that by removing the portion of variance shared by semantic similarity with relevance, semantic similarity effects still show significant. To test this, we regressed semantic similarity on relevance and relatedness and included its residuals as predictor, together with relevance, relatedness, and task, in a new model. As expected, and contrary to the residualized response relevance and relatedness, semantic similarity was still significant ($\beta = 8.839$; $t(22725) = 3.99$) after residualization on relevance and relatedness. This confirms that relevance and relatedness do not add any predictive information for the observed effects once semantic similarity is taken into account.

4. Discussion

In the present study we tested a central assumption of the response exclusion account according to which, distractor-induced interference effects are determined by the response relevant status of distractor words, rather than their semantic relation with the target. Often, these two factors are confounded. To disentangle the individual contributions of item-inherent categorical relatedness and task-related response relevance effects, we combined the picture–word interference paradigm with the conditional naming task in an orthogonal design, varying categorical relatedness and response relevance independent of each other. The pattern of results across two tasks, conditional and free naming, together with the semantic similarity ratings, suggests that response relevance is not the critical factor for interference effects in the PWI paradigm. Instead, and in line with lexical competition models, the observed data can best be accounted for with graded effects of semantic similarity beyond classic categorical relations, as discussed in detail below.

4.1. The relevance of response relevance

In the conditional naming task we found an effect of response relevance, with slower latencies for task-relevant relative to irrelevant words. By itself, this effect confirms one of the central predictions derived from the response exclusion account, suggesting that response relevance does contribute to semantic interference effects. However, two observations lead us to a different conclusion.

First, and most importantly, distractors classified as response relevant in the conditional naming task induced slower naming latencies even in a free naming task in which all presented pictures are named in an unconstrained fashion. We found numerically very similar differences between relevant and irrelevant conditions in the two tasks and, critically, no interaction of task and response relevance, which should have been observed according to the response exclusion account. This holds for the categorically related as well as for the unrelated condition — in both cases we find comparable effects of response relevance in the two tasks. Because the criteria specified by the conditional naming instruction are not applicable in the free naming task, the effects of "response relevance" in this task must be due to other variables that vary systematically with this factor. We have suggested that systematic differences between relevant and irrelevant distractors in terms of semantic similarity may account for the observed slowing of RTs for the relevant relative to the irrelevant distractors because response relevance was determined by a semantic property (see discussion below).

Second, we found a categorically induced interference effect in the conditional naming task which was not predicted by the response exclusion hypothesis. According to this hypothesis, given equal levels of response relevance, semantically related distractors should induce facilitation, rather than interference. We have presumed such equal levels of relevance in conditional naming because semantic category membership was an inappropriate response relevant criterion — category members were as likely to be response relevant as unrelated distractors. Thus, if this assumption holds, categorically related relevant distractors should induce facilitation relative to unrelated relevant distractors, and categorically related irrelevant distractors should likewise induce facilitation relative to the unrelated counterparts. However, and in line with lexical competition models, we observed the opposite pattern, namely, a classic semantic interference effect that most likely reflects lexical competition.

To explain similar distractor effects in the two tasks, advocates of the response exclusion account could argue for a two-step mechanism in the conditional naming task. First, the conditional naming criterion is applied on the picture, and in a second step name retrieval occurs, for go-trials, similarly to the free naming task. This way, the categorical dimension is the only response relevant criterion in both tasks, and thus, similar distractor effects would be observed. However, serial completion of the response decision and name retrieval can be excluded based on previous evidence. Mulatti et al. (2010) demonstrated that conditional naming costs reflect response-driving categorization. Critically, only a fraction of the time needed for the response-driving categorization (as assessed by binary semantic decisions) emerges in conditional naming. This implies that during conditional naming the response-driving categorization occurs at early stages and can run in parallel with name retrieval processes. This is in line with EEG data of our own, in which the same stimuli elicit similar brain potentials in free and conditional naming, and task-driven amplitude modulations arise as early as 150 ms after stimulus onset (Aristei et al., 2007). Based on this data, a two-step mechanism is unlikely.

Also the reported evidence suggests that the task effects we observe, i.e. longer naming latencies infor conditional than free naming, reflect semantic categorization processes. It could nonetheless be argued that, given the criterion we employed, a late stage of the response decision processes within the conditional naming task cannot be excluded. And this might account for the absence of task-dependent response relevance effects. A late locus of the response decision though would not alter the predictions for the present experiment. Within the REH as well, it is unclear whether the response decision mechanism operates at early or late stages along the language production stream (e.g., Costa et al., 2005; D'hooge & Hartsuiker, 2010; Mahon et al., 2007; for different assumptions). However, irrespective of different functional loci assumed for the response exclusion mechanism, proponents of the REH agree that response relevance effects arise because words *always* occupy the output buffer prior to picture names, and this process has access to word semantic information (e.g. Janssen et al., 2008). This situation is expected to similarly persist in conditional naming after – for go trials – the decision to respond is made. In the present conditional naming task, the semantic categorization of an object as a target object would allow the exclusion mechanism to classify a distractor either as relevant or irrelevant, and therefore relevance, but not semantic relatedness, should drive interference effects.

In addition, one could argue that, by the time a response decision on the picture has been taken, word distractors already entered and left the output buffer. If so, we should observe no distractor interference at all, which is in contrast to our findings.

Proponents of the response exclusion account may also claim that the conditional naming criterion used in the present experiment is ill-chosen, as "no one" would assume that whether something is found in the water is a relevant dimension for producing semantic interference. However, we consider the criterion applied here not to be ill-chosen for several reasons. First, the typical place of occurrence can be viewed as a rather basic semantic feature. In fact, we do find that naming times (e.g., for the target canoe) are slower for categorically unrelated distractors that belong to the target's semantic theme (e.g., fish) than for distractors that don't (e.g., dog). This finding is not incidental, and it is in line with recent evidence for a flexible architecture of the lexical/semantic side of the language production system. Previous studies show that interference is not restricted to categorical relations but it extends also to associative and thematic relations, and even ad-hoc created categories for event themes that are stored in long-term memory (e.g. Abdel Rahman & Melinger, 2007, 2011; Melinger & Abdel Rahman, 2012 see also Barsalou, 1983, 1985, 1991, 1993, 2007; Vallée-Tourangeau, Anthony, & Austin, 1998).

Moreover, proponents of the response exclusion hypothesis have suggested response-relevant criteria other than categorical dimension, such as word-class and part-whole dimensions that are applied by participants on the basis of their experience with the task at hand (Costa et al., 2005; Mahon et al., 2007). In light of these considerations the typical place of occurrence does not seem particularly remote.[3]

The appropriateness of the conditional naming criterion might be questioned on the basis of its explicit nature, with the argument that semantic interference can only be induced by response relevant criteria implicitly extracted or even automatically activated. However, this is in contrast to the claims of the response exclusion account that explicit task instructions are critical in the definition of the response relevant status of distractor words, and responsible for reversals of categorical interference into facilitation effects for identical stimuli (e.g., Mahon et al., 2007; but see La Heij, Dirkx, & Kramer, 1990; Kuipers et al., 2006). Thus, the conditional naming instructions employed here are an appropriate operationalization of response relevance, and able to overrule item-inherent coarse semantic information.

Despite differences in the experimental design and rationale, a previous PWI study by La Heij (1988) showed similar effects as the ones presented here, i.e., additive effects of semantic relatedness and response relevance (that was determined by task instructions in terms of response set categories, e.g., "name tools and musical instruments"). La Heij attributed both, relevance and semantic interference effects to enhanced lexical competition due to stronger conceptual priming and semantic relatedness (see Bloem & La Heij, 2003; Bloem et al., 2004; for an implementation of the two mechanisms in the Conceptual Selection Model — CSM). This way response relevance and semantic relatedness effects can be accommodated with conceptual priming and lexical competition as the basis for semantic facilitation and interference effects, thus providing a parsimonious alternative account to the response exclusion hypothesis.

However, task-driven priming cannot be easily applied to our "response relevance" results in free naming. In La Heij's study a very small stimulus set (6 objects, from 2 categories that were presented 48 times) enables the retention of the response set in short term memory, against which distractors can be identified as parts of the response set category. In contrast, in the present study the large stimulus set (100 target pictures; 100 distractor words that are not part of the response set) prevented such a mechanism. Therefore, a difference in terms of semantic similarity behind the observed relevance effects constitutes the most parsimonious account for similar relevance effects in the conditional and free naming tasks. Interestingly, the account proposed by La Heij for response relevance effects in his study is compatible with ours, and both can be accommodated by the lexical selection by competition hypothesis, without the assumption of a post-lexical mechanism.

To summarize, we conclude that response relevant distractors in the present study share the semantic property of being located in or outside the water and associated features, making these distractors semantically more similar than those not sharing these criteria. Response relevance does not seem to be a critical factor for interference effects in the PWI paradigm. Instead, semantic similarity between target and distractor has a strong influence on naming latencies, irrespective of the response relevant status, and beyond categorical membership. The effects of semantic similarity are discussed in detail in the following section.

4.2. Effects of semantic similarity

In line with lexical competition models we found classic categorically induced semantic interference effects in both, the conditional and the free naming task. According to the response exclusion account we expected a different pattern. This account predicts categorically induced facilitation in the conditional naming task (within the levels of response relevance) and categorically induced interference in the free naming task. We have suggested that systematic differences between relevant and irrelevant distractors may account for the observed slowing of RTs in the relevant relative to the irrelevant distractors because response relevance was determined by a semantic property. The semantic similarity rating yielded strong evidence for this assumption, demonstrating that target-distractor combinations associated with the response relevant condition (in the conditional naming task) were rated as more similar than combinations in the irrelevant condition (Fig. 2). Moreover, the statistical analyses revealed high correlations not only between categorical relatedness and semantic similarity, but also between response

[3] To exclude that previous experience with the conditional naming criterion (due to the familiarization procedure or prior conditional naming blocks) could have modulated the response relevance effects in the free naming task, we conducted an ANOVA with task, relatedness, and relevance as within-participant factors, and order of the tasks as between-participant factor at two levels (free naming as first task, free naming as second or third task). Results yielded no interaction between task order and any of the other factors (all $Fs < 1$). Furthermore, the costs associated with conditional naming (compared to free naming) suggest that the criterion did not play a major role in the free naming task. We therefore conclude that it is theoretically possible but unlikely that the familiarization and conditional naming experience induced the observed effects in the free naming task. Additionally, an ANOVA with the order of the two conditional naming tasks as between participant factor also revealed no interaction with any of the other variables (i.e., task, relatedness, and relevance) (all $ps > .1$; smallest $p = .15$).

relevance and semantic similarity. Removing the portion of variance shared by these two experimental factors with semantic similarity, no traces of either response relevance or categorical relatedness effects remained.

These results strongly suggest that semantic similarity is the most critical factor in determining interference effects in both, the conditional and the free naming task. Graded differences in semantic similarity can account not only for the effects of categorical relatedness, but also for the effects of response relevance in the conditional and free naming tasks.

Furthermore, we found that increasing levels of semantic similarity between targets and distractors in the related and unrelated condition were associated with enhanced interference effects in both tasks. The polarity of semantic similarity effects observed here is opposite to the effects predicted by the response exclusion account: given equal levels of response relevance, semantically similar distractors should yield priming-induced facilitation relative to more dissimilar distractors. In contrast, our data replicates previous work showing inhibitory effects of graded semantic similarity (e.g. Abdel Rahman et al., 2010; Lee & de Zubicaray, 2010; Vigliocco et al., 2002, 2004). Here, we demonstrate such semantic similarity effects not only for categorically related but also for unrelated words. For instance, the target sailboat is named slower in the context of the distractor word "prawn" than in the context of the distractor "worm", despite the fact that both words are categorically unrelated. In line with Vigliocco et al. (2002, 2004), we conclude that graded semantic similarity is reflected in gradually enhanced semantic interference effects within and beyond classic categorical relations.

As discussed in the Introduction section, these findings are in contrast to semantic similarity effects reported by Mahon et al. (2007), showing faster RTs for similar compared to dissimilar distractors, given equal levels of response relevance (defined by category membership). Apparent differences between Mahon et al.'s study and ours, such as different stimulus set size (36 or less vs. 100), or different semantic distance measures (binary vs. continuous) are unlikely origins of the discrepant results. Vigliocco et al. (2004) found larger interference effects for semantically similar than dissimilar concepts with 24 items, and previous findings as well as our own data showed increasing semantic interference also with a discrete classification of semantic similarity (Abdel Rahman et al., 2010; Lee & de Zubicaray, 2010; Vigliocco et al., 2002, 2004; see also Aristei et al., 2010).

A striking difference between Mahon et al. and our study is the distractor presentation modality (visual vs. auditory). The REH does not distinguish between written and spoken distractor effects (e.g., Mahon et al., 2007, p. 506), and at negative SOAs, at which facilitatory effects of semantic similarity were more robust in Mahon et al.'s study, written and spoken words have been shown to exert similar interference effects (e.g. Damian & Martin, 1999; Roelofs, 2005; Schriefers et al., 1990; Starreveld, 2000). Therefore, distractor presentation modality cannot account for the discrepancy. Nevertheless, it remains unclear why spoken distractors should be processed as potentially relevant responses. In contrast to visual words that are in the focus of visual attention during picture naming, auditory words could easily be identified as irrelevant based on presentation modality even before access to semantic information (see Driver & Spence, 1998; Tellinghuisen & Nowak, 2003; for crossmodal attention effects). This seems to challenge core assumptions of the REH. Model's underspecification though, of why and how response relevant criteria such as semantic content are prioritized over more elementary dimensions such as presentation modality, limits an in-depth discussion of this issue (but see Mulatti & Coltheart, 2012).

For the present study we conclude that the categorically induced interference effects observed across tasks, and the inhibitory nature of the graded semantic similarity effects found here are most easily accounted for by models assuming that lexical selection is a competitive process.

4.3. Conclusions

To summarize, we found no evidence for response relevance as a major source of semantic interference effects in the PWI paradigm. In contrast, our data demonstrate that graded semantic similarity, rather than response relevance, is critical for interference effects to be observed. These semantic effects cross category boundaries, suggesting a flexible architecture of the production system. Furthermore, graded semantic similarity effects are inhibitory, not facilitatory. Together, these findings support the assumption that lexical selection is a competitive process and that semantic interference effects in the PWI paradigm reflect this competition.

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Appendix

Target	Distractor			
In or on the water	Related		Unrelated	
	Relevant	Irrelevant	Relevant	Irrelevant
Means of transportation				
Segelboot	Katamaran	Tandem	Garnele	Wurm
(sailboat)	(Catamaran)	(Tandem)	(Prawn)	(Worm)
Floß	Galeere	Zeppelin	Biber	Spinne
(Raft)	(Galley)	(Zeppelin)	(Beaver)	(Spider)
Kanu	Tretboot	Helicopter	Forelle	Schnecke
(Canoe)	(Paddleboat)	(Helicopter)	(Trout)	(Snail)
U-boot	Einbaum	Roller	Qualle	Gecko
(Submarine)	(Logboat)	(Scooter)	(Jellyfish)	(Gecko)
Fähre	Luftkissenboot	Motorrad	Schwan	Scorpion
(Ferry)	(Hovercraft)	(Motorbike)	(Swan)	(Scorpion)
Yacht	Galeone	Kutsche	Schwertfisch	Schlange
(Yacht)	(Galleon)	(Carriage)	(Swordfish)	(Snake)

Appendix (*continued*)

Target	Distractor			
In or on the water	Related		Unrelated	
	Relevant	Irrelevant	Relevant	Irrelevant
Means of transportation				
Surfbrett	Karavelle	Zug	Kaulquappe	Grille
(Surfboard)	(Caravel)	(Train)	(Pollywog)	(Cricket)
Gondel	Motorboot	Snowboard	Languste	Nashorn
(Gondola)	(Motorboat)	(Snowboard)	(Crawfish)	(Rhino)
Fischkutter	Schlauchboot	Rettungswagen	Sardelle	Elefant
(Fishing cutter)	(Dinghy)	(Ambulance)	(Anchovy)	(Elefant)
Lufmatratze	Kajak	Fahrrad	Seestern	Storch
(Airbed)	(Kayak)	(Bicycle)	(Starfish)	(Stork)
Öltanker	Schaluppe	Lkw	Muräne	Kuh
(Oil tanker)	(Shallop)	(Truck)	(Moray)	(Cow)
Tools				
Anker	Torpedo	Pflock	Plankton	Trüffel
(Anchor)	(Torpedo)	(Picket)	(Plankton)	(Truffel)
Paddel	Ruderblatt	Schläger	Mangrove	Veilchen
(Paddle)	(Rudder blade)	(Bat)	(Mangrove)	(Violet)
Harpune	Köder	Messer	Seetang	Pilz
(Harpoon)	(Lure)	(Knife)	(Seaweed)	(Mushroom)
Fischernetz	Reuse	Sieb	Koralle	Dattelpalme
(Fishing net)	(Bow net)	(Colander)	(Coral)	(Date palm)
Boje	Segel	Leitpfosten	Moos	Weizen
(Buoy)	(Sail)	(Reflector post)	(Moss)	(Wheat)
Staudamm	Pier	Brücke	Flechte	Bambus
(Dam)	(Pier)	(Bridge)	(Lichen)	(Bamboo)
Angelhaken	Tauchermesser	Spiess	Brunnenkresse	Efeu
(Fishhook)	(Diving knife)	(Spit)	(Watercress)	(Ivy)
Garments				
Flossen	Schwimmbrille	Schuhe	Albatross	Adler
(Fins)	(Goggles)	(Shoes)	(Albatross)	(Eagle)
Tauchermaske	Badelatschen	Schal	Hering	Schmetterling
(Diving mask)	(Flip-flops)	(Scarf)	(Herring)	(Butterfly)
Schnorchel	Nasenklemme	Brille	Wels	Raupe
(Snorkel)	(Nose clips)	(Glasses)	(Catfish)	(Caterpillar)
Bikini	Taucherglocke	Unterhose	Nilpferd	Eidechse
(Bikini)	(Diving bell)	(Underpants)	(Hyppo)	(Lizard)
Badekappe	Taucheruhr	Hut	Seeigel	Hund
(Cap)	(Diving watch)	(Cap)	(Sea urchin)	(Dog)
Schwimmreifen	Rettungsring	Gürtel	Tunfisch	Maus
(Floating tire)	(Lifesaver)	(Belt)	(Tuna)	(Mouse)
Taucheranzug	Schwimmweste	Hose	Krebs	Ameise
(Diving-suit)	(Lifejacket)	(Pants)	(Crab)	(Ant)
Plants				
Alge	Seetang	Trüffel	Taucheruhr	Gürtel
(Algae)	(Seaweed)	(Truffel)	(Diving watch)	(Belt)
Seerose	Plankton	Veilchen	Katamaran	Tandem
(Water lily)	(Plankton)	(Violet)	(Catamaran)	(Tandem)
Schwamm	Koralle	Pilz	Tretboot	Hose
(Sponge)	(Coral)	(Mushroom)	(Paddleboat)	(Pants)
Farn	Moos	Efeu	Galeere	Unterhose
(Floating fern)	(Moss)	(Ivy)	(Galley)	(Underpants)
Schilf	Flechte	Bambus	Einbaum	Brille
(Reed)	(Lichen)	(Bamboo)	(Logboat)	(Glasses)
Papyrus	Mangrove	Dattelpalme	Kajak	Zeppelin
(Bulrush)	(Mangrove)	(Date palm)	(Kayak)	(Zeppelin)
Reis	Brunnenkresse	Weizen	Karavelle	Schuhe
(Rice)	(Watercress)	(Wheat)	(Caravel)	(Shoes)
Animals				
Hai	Schwertfisch	Wurm	Luftkissenboot	Roller
(Shark)	(Swordfish)	(Worm)	(Hovercraft)	(Scooter)
Wal	Forelle	Elefant	Motorboot	Helicopter
(Whale)	(Trout)	(Elefant)	(Motorboat)	(Helicopter)
Seepferd	Biber	Kuh	Torpedo	Kutsche
(Seahorse)	(Beaver)	(Cow)	(Torpedo)	(Carriage)
Octopus	Qualle	Schnecke	Galeone	Motorrad
(Octopus)	(Jellyfish)	(Snail)	(Galleon)	(Motorbike)
Aal	Kaulquappe	Schlange	Schaluppe	Snowboard
(Eel)	(Pollywog)	(Snake)	(Shallop)	(Snowboard)
Goldfisch	Wels	Scorpion	Schlauchboot	Rettungswagen
(Goldfish)	(Catfish)	(Scorpion)	(Dinghy)	(Ambulance)
Karpfen	Hering	Gecko	Ruderblatt	Zug
(Carp)	(Herring)	(Gecko)	(Rudder blade)	(Train)

(*continued on next page*)

Appendix (*continued*)

Target	Distractor			
In or on the water	Related		Unrelated	
	Relevant	Irrelevant	Relevant	Irrelevant
Animals				
Penguin (Penguin)	Schwan (Swan)	Storch (Stork)	Köder (Lure)	Fahrrad (Bicycle)
Robbe (Seal)	Nilpferd (Hippo)	Nashorn (Rhino)	Segel (Sail)	Lkw (Truck)
Krabbe (Shrimp)	Seeigel (Sea urchin)	Schmetterling (Butterfly)	Pier (Pier)	Pflock (Picket)
Muschel (Scallop)	Seestern (Starfish)	Grille (Cricket)	Reuse (Bow net)	Leitpfosten (Reflector post)
Rochen (Ray)	Muräne (Moray)	Spinne (Spider)	Schwimmweste (Lifejacket)	Messer (Knife)
Schildkröte (Turtle)	Krebs (Crab)	Maus (Mouse)	Rettungsring (Lifesaver)	Brücke (Bridge)
Krokodil (Crocodile)	Languste (Crawfish)	Eidechse (Lizard)	Badelatschen (Flip-flops)	Schläger (Bat)
Dolphin (Dolphin)	Tunfisch (Tuna)	Hund (Dog)	Taucherglocke (Diving bell)	Spiess (Spit)
Frosch (Frog)	Garnele (Prawn)	Raupe (Caterpillar)	Schwimmbrille (Goggles)	Sieb (Colander)
Lachs (Salmon)	Sardelle (Anchovy)	Ameise (Ant)	Nasenklemme (Nose clips)	Schal (Scarf)
Ente (Duck)	Albatross (Albatross)	Adler (Eagle)	Tauchermesser (Diving knife)	Hut (Cap)

Target	Distractor			
Outside the water	Related		Unrelated	
	Relevant	Irrelevant	Relevant	Irrelevant
Means of transportation				
Flugzeug (Airplane)	Helicopter (Helicopter)	Luftkissenboot (Hovercraft)	Trüffel (Truffel)	Mangrove (Mangrove)
Fallschirm (Parachute)	Zeppelin (Zeppelin)	Katamaran (Catamaran)	Veilchen (Violet)	Moos (Moss)
Bus (Bus)	Lkw (Truck)	Galeere (Galley)	Pilz (Mushroom)	Koralle (Coral)
Rollschuh (Roller-skate)	Snowboard (Snowboard)	Einbaum (Logboat)	Efeu (Ivy)	Seetang (Seaweed)
Kinderwagen (Buggy)	Fahrrad (Bicycle)	Tretboot (Paddleboat)	Bambus (Bamboo)	Flechte (Lichen)
Sessellift (Chairlift)	Kutsche (Carriage)	Kajak (Kayak)	Weizen (Wheat)	Plankton (Plankton)
Schlitten (Sledge)	Roller (Scooter)	Motorboot (Motorboat)	Dattelpalme (Date palm)	Brunnenkresse (Watercress)
Wohnmobil (Camper)	Zug (Train)	Karavelle (Caravel)	Elefant (Elefant)	Schwertfisch (Swordfish)
Auto (Car)	Rettungswagen (Ambulance)	Galeone (Galleon)	Wurm (Worm)	Forelle (Trout)
Flugdrachen (Hang-glider)	Tandem (Tandem)	Schaluppe (Shallop)	Kuh (Cow)	Biber (Beaver)
Hubschrauber (Whirlybird/eggbeater)	Motorrad (Motorbike)	Schlauchboot (Dinghy)	Schnecke (Snail)	Kaulquappe (Pollywog)
Tools				
Rakete (Missile)	Pflock (Picket)	Torpedo (Torpedo)	Nashorn (Rhino)	Schwan (Swan)
Fahne (Flag)	Leitpfosten (Reflector post)	Segel (Sail)	Storch (Stork)	Wels (Catfish)
Schere (Scissors)	Messer (Knife)	Tauchermesser (Diving knife)	Gecko (Gecko)	Hering (Herring)
Knüppel (Bludgeon)	Schläger (Bat)	Ruderblatt (Rudder blade)	Spinne (Spider)	Qualle (Jellyfish)
Käfig (Cage)	Sieb (Colander)	Reuse (Bow net)	Schlange (Snake)	Nilpferd (Hyppo)
Turm (Tower)	Brücke (Bridge)	Pier (Pier)	Scorpion (Scorpion)	Seeigel (Sea urchin)
Nadel (Needle)	Spiess (Spit)	Köder (Lure)	Grille (Cricket)	Garnele (Prawn)
Garments				
Pantoffeln (Slippers)	Schuhe (Shoes)	Badelatschen (Flip-flops)	Raupe (Caterpillar)	Muräne (Moray)
Jacke (Jacket)	Schal (Scarf)	Taucheruhr (Diving watch)	Schmetterling (Butterfly)	Seestern (Starfish)

Appendix (*continued*)

Target	**Distractor**			
In or on the water	Related		Unrelated	
	Relevant	Irrelevant	Relevant	Irrelevant
Garments				
Kapuze (Hood)	Hut (Cap)	Taucherglocke (Diving bell)	Hund (Dog)	Languste (Crawfish)
Pajama (Pajama)	Unterhose (Underpants)	Rettungsring (Lifesaver)	Eidechse (Lizard)	Tunfisch (Tuna)
Hosenträger (Suspender)	Gürtel (Belt)	Nasenklemme (Nose clips)	Maus (Mouse)	Sardelle (Anchovy)
Ohring (Earring)	Brille (Glasses)	Schwimmbrille (Goggles)	Adler (Eagle)	Krebs (Crab)
Pullover (Sweater)	Hose (Pants)	Schwimmweste (Lifejacket)	Ameise (Ant)	Albatross (Albatross)
Plants				
Kastanie (Chestnut)	Trüffel (Truffel)	Plankton (Plankton)	Tandem (Tandem)	Luftkissenboot (Hovercraft)
Basilikum (Basil)	Dattelpalme (Date palm)	Mangrove (Mangrove)	Zeppelin (Zeppelin)	Katamaran (Catamaran)
Zwiebel (Onion)	Pilz (Mushroom)	Moos (Moss)	Roller (Scooter)	Galeere (Galley)
Rebe (Vine)	Efeu (Ivy)	Seetang (Seaweed)	Helicopter (Helicopter)	Kajak (Kayak)
Kohlrabi (Kohlrabi)	Bambus (Bamboo)	Flechte (Lichen)	Motorrad (Motorbike)	Einbaum (Logboat)
Dill (Dill)	Veilchen (Violet)	Koralle (Coral)	Zug (Train)	Tretboot (Paddleboat)
Hafer (Oat)	Weizen (Wheat)	Brunnenkresse (Watercress)	Kutsche (Carriage)	Karavelle (Caravel)
Animals				
Katze (Cat)	Wurm (Worm)	Schwertfisch (Swordfish)	Snowboard (Snowboard)	Motorboot (Motorboat)
Zebra (Zebra)	Elefant (Elefant)	Forelle (Trout)	Rettungswagen (Ambulance)	Galeone (Galleon)
Giraffe (Giraffe)	Kuh (Cow)	Nilpferd (Hyppo)	Lkw (Truck)	Schlauchboot (Dinghy)
Wiesel (Weasel)	Schnecke (Snail)	Kaulquappe (Pollywog)	Fahrrad (Bicycle)	Schaluppe (Shallop)
Maulwurf (Mole)	Schlange (Snake)	Qualle (Jellyfish)	Pflock (Picket)	Torpedo (Torpedo)
Affe (Monkey)	Scorpion (Scorpion)	Wels (Catfish)	Leitpfosten (Reflector post)	Segel (Sail)
Eule (Owl)	Schmetterling (Butterfly)	Schwan (Swan)	Sieb (Colander)	Pier (Pier)
Moskito (Mosquito)	Storch (Stork)	Hering (Herring)	Schläger (Bat)	Köder (Lure)
Pferd (Horse)	Nashorn (Rhino)	Biber (Beaver)	Messer (Knife)	Ruderblatt (Rudder blade)
Igel (Urchin)	Spinne (Spider)	Garnele (Prawn)	Brücke (Bridge)	Reuse (Bow net)
Schaf (Sheep)	Grille (Cricket)	Seeigel (Sea urchin)	Unterhose (Underpants)	Nasenklemme (Nose clips)
Käfer (Bug)	Raupe (Caterpillar)	Muräne (Moray)	Schuhe (Shoes)	Schwimmbrille (Goggles)
Hase (Hare)	Gecko (Gecko)	Seestern (Starfish)	Schal (Scarf)	Tauchermesser (Diving knife)
Huhn (Hen)	Eidechse (Lizard)	Languste (Crawfish)	Spiess (Spit)	Taucheruhr (Diving watch)
Löwe (Lion)	Hund (Dog)	Tunfisch (Tuna)	Hut (Cap)	Rettungsring (Lifesaver)
Hamster (Hamster)	Maus (Mouse)	Krebs (Crab)	Gürtel (Belt)	Taucherglocke (Diving bell)
Eichorchen (Squirrel)	Ameise (Ant)	Albatross (Albatross)	Brille (Glasses)	Badelatschen (Flip-flops)
Papagei (Parrot)	Adler (Eagle)	Sardelle (Anchovy)	Hose (Pants)	Schwimmweste (Lifejacket)

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