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Cumulative semantic interference for associative relations in language production

Sebastian Benjamin Rose *, Rasha Abdel Rahman

Institut für Psychologie, Humboldt-Universität zu Berlin, Rudower Chaussee 18, 12489 Berlin, Germany

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ABSTRACT

Associations between conceptual representations and thematic relations play an important role in the organization of semantic memory. However, language production research on semantic context effects shows that associative (e.g., dog and bone) and categorical relations (dog and horse) seem to diverge. While categorical contexts typically induce semantic interference that has traditionally been taken to reflect competitive lexical selection, evidence for comparable associative modulations is rare. In three experiments we tested whether thematic associations between objects induce cumulative interference in the continuous naming paradigm, assuming that this paradigm hampers lexical selection via the activation of highly active lexical cohorts steadily increasing in size. Indeed, naming times increased linearly with each newly named member of thematic contexts irrespective of the pre-activation of associations before the naming task (Experiment 1), and irrespective of whether categorical links were partially included (Experiments 1 and 2) or entirely absent (Experiment 3). These findings demonstrate that different types of semantic relations induce interference.

1. Introduction

Language production involves conceptual, lexical and morphophonological processes (cf. Levelt, 1992; Levelt, Roelofs, & Meyer, 1999). For instance, during picture naming the visual presentation of an object triggers the activation of its concept (e.g., dog), and in turn the activation of the corresponding lexical entry, the lemma (*dog*). Simultaneously, activation spreads to semantically related concepts (e.g., horse, cat, mouse, etc.) and their lexical representations, resulting in the reciprocal activation of related items at the conceptual and lexical level. The selection of the target from among several co-activated lemmas is a core aspect of language production (e.g., Dell, 1986; Levelt et al., 1999; Mahon, Costa, Peterson, Vargas, & Caramazza, 2007; Roelofs, 1992; Roelofs, 2003).

Different semantic context manipulations have been employed to gain insight into the mechanisms underlying lexical selection. For example, in the picture word interference (PWI) paradigm a picture is named while a simultaneously presented distractor word should be ignored. When the word is categorically related (target: dog, distractor: horse), naming times are longer than in an unrelated condition (e.g., Damian & Bowers, 2003; Glaser & Dungelhoff, 1984; Glaser & Glaser, 1989; Hantsch, Jescheniak, & Schriefers, 2005; La Heij, 1988; Schriefers, Meyer, & Levelt, 1990; Vitkovitch & Tyrrell, 1999). Interference has also been observed in the cyclic naming paradigm in which pictures are repeatedly named in blocks consisting of objects from the same category (all objects are animals; homogeneous blocks) or from different semantic categories (heterogeneous blocks) (e.g., Belke, Meyer, & Damian, 2005; Damian & Als, 2005; Damian, Vigliocco, & Levelt, 2001; Kroll & Stewart, 1994; Schnur, Schwartz, Brecher, & Hodgson, 2006; Vigliocco, Vinson, Damian, & Levelt, 2002). These semantic interference effects have traditionally been taken to reflect lexical competition during lemma retrieval (e.g., Levelt et al., 1999; Roelofs, 1992). Specifically, it is assumed that co-activated lemmas directly compete with the target for selection, thus delaying selection (for current alternative accounts, see Section 5.1).

Evidence for semantic interference stems predominantly from investigations of categorical relations. Even though word meaning is not exclusively composed of categorical relations, and even though non-categorical semantic links such as associations and thematic ties play an important role in the organization of the conceptual system (Barsalou, 2008; Estes, Golonka, & Jones, 2011; McRae, Khalkhali, & Hare, 2012), non-categorical associative context effects have thus far received comparatively little attention in language production research. In contrast to category members that share semantic features and category nodes, associatively

* Corresponding author.
E-mail addresses: sebastian.rose@hu-berlin.de (S.B. Rose), rasha.abdel.rahman@hu-berlin.de (R. Abdel Rahman).

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related concepts can be viewed as elements of specific situations or thematic contexts, with little or no overlap between their semantic features (e.g., farm: cow and tractor) (Abdel Rahman & Melinger, 2007; Abdel Rahman & Melinger, 2011; Barsalou, 1983; Estes et al., 2011). Such relations may help us to communicate and interact appropriately with our environment, for instance, by generating hypotheses about what to expect in specific situations or during conversations (e.g., Bar, 2004; Bar & Aminoff, 2003; Estes et al., 2011; Kveraga et al., 2011; McRae et al., 2012; van der Meer, 1991). Yet, most PWI studies found that associatively related distractors have no effects or facilitate naming, in contrast to the interference robustly observed for categorically related words (e.g., Abdel Rahman & Melinger, 2007; Alario, Segui, & Ferrand, 2000; Aristei, Melinger, & Abdel Rahman, 2010; de Zubicaray, Hansen, & McMahon, 2013; La Heij, Dirkx, & Kramer, 1990; for part–whole relations: Costa, Alario, & Caramazza, 2005). Thus, empirical reports of associative interference are rare, and the question whether they affect lexical–semantic processes during speech planning in a similar way as categorical relations remains open.

It has been argued that context induced facilitation effects contradict lexical competition models, and that the "default" pattern in language production is facilitation, rather than interference (Mahon et al., 2007; Navarrete, Del Prato, & Mahon, 2012; Navarrete, Del Prato, Peressotti, & Mahon, 2014). However, semantic facilitation is not per se at odds with competition models, as recently discussed, for instance, by Roelofs and Piai (2015; see also: Roelofs, 2003), showing that WEAVER++ could also simulate facilitation for associatively related distractors in a Stroop task (see also Mahon, Garcea, & Navarrete, 2012; Mahon & Navarrete, 2014; Roelofs & Piai, 2013; Roelofs & Piai, 2015). Indeed, many production models incorporate the idea of concurrent activation patterns with priming at the conceptual level and interference at the lexical level (e.g., Belke, 2013; Levelt et al., 1999; Roelofs, 1992, 2003). This aspect has been highlighted most explicitly in the swinging lexical network account (SLN) (Abdel Rahman & Melinger, 2009a, 2009b). In the SLN, semantic context effects are assumed to be the product of a trade-off between facilitatory semantic priming at the conceptual level and concomitant inhibitory competition at the lexical level. Hence, semantic facilitation and interference are two sides of the same coin, and the polarity of the overall net effects depends on the outcome of the trade-off, with facilitation when conceptual priming dominates and inhibition when lexical interference dominates. The main factor for lexical competition to outweigh conceptual facilitation is the activation of a lexical cohort, that is, the activation of a number of co-activated and inter-related competitors that mutually enhance each other's levels of activation, with each competitor contributing to the competition, resulting in strong overall semantic interference.

Importantly, according to the SLN associatively and categorically related concepts differ in their capacity to induce the activation of lexical cohorts. Categorical relations (e.g., cat and horse) naturally share semantic features (e.g., fur, four legs, etc.) and category nodes (mammals), thus co-activating other category members sharing these features (Abdel Rahman & Melinger, 2007; Estes et al., 2011; McRae et al., 2012; Rabovsky, Schad, & Abdel Rahman, 2016). In contrast, associatively related concepts (e.g., pitchfork and hay bale) usually serve Complementary roles within specific contexts or themes, and do not share category nodes or a significant number of semantic features (cf. Muehlhaus et al., 2013; Muehlhaus et al., 2014; Sass et al., 2010; Schwartz et al., 2011). Therefore, lexical cohort activation and semantic interference effects are less likely for associates, and conceptual facilitation typically dominates. Accordingly, in the PWI task categorically related words induce the activation of a lexical cohort of inter-related items mutually co-activating each other, whereas associative distractors tend to have a one-to-one relation with the target picture, and no reciprocal activation between interrelated nodes is achieved (Abdel Rahman & Melinger, 2007; de Zubicaray, Hansen, et al., 2013; see also Muehlhaus et al., 2014; Sailor & Brooks, 2014; Vieth, McMahon, & de Zubicaray, 2014b, for similar argumentations for part–whole relations). Therefore, semantic interference will not outperform facilitative conceptual effects, and facilitation should be observed (Abdel Rahman & Melinger, 2009a, 2009b; Melinger & Abdel Rahman, 2013). In other words, associatively and categorically related word distractors induce conceptual facilitation and simultaneous lexical interference – with the critical difference that interference will typically dominate in the latter case because cohort-induced competition outweighs facilitation, whereas (weak) facilitation or no effects dominate in the former case because associates tend to have one-to-one relations and do not activate lexical cohorts.

The SLN predicts associatively induced interference should be observed when the activation of a lexical cohort is promoted and/or when conceptual facilitation is minimized. Indeed, Abdel Rahman and Melinger (2007) demonstrated interference when associates were inter-related by a common theme (e.g., apiary: bee, honey, honey comb, etc.) in the cyclic blocking paradigm. In contrast to the one-to-one activation pattern in the PWI task, the blocked and repeated presentation of associatively related items belonging to a given theme resulted in a higher degree of lexical cohort activation, and this was reflected in semantic interference – even though the effects were smaller and seemed to be less stable than categorical effects (cf. de Zubicaray, Johnson, Howard, & McMahon, 2014). Furthermore, in a PWI task, the presentation of word distractors that are phonologically related (e.g., camera) to an associate (camel) of a target (pyramid) yielded small traces of mediated semantic interference effects (Melinger & Abdel Rahman, 2013). This is because the distractors activate the lexical competitor via shared phonology while the activation of the associate's conceptual representations should be minimized. Just like in the blocking paradigm, this effect was small, and present only when the associates were parts of the response set. Taken together, even though rare, some observations of associative interference suggest that these relations are co-activated at the lexical level. However, the effects reported thus far in the PWI and cyclic blocking paradigm are relatively subtle and need replications (cf. de Zubicaray et al., 2014). The aim of the present study was to test for associative interference by employing a different naming paradigm, the continuous version of the cyclic semantic blocking task (Brown, 1981; Howard, Nickels, Coltheart, & Cole-Virtue, 2006). This paradigm should reveal stronger interference for associates than reported before, as outlined below.

1.1. Cumulative associative interference in the continuous naming paradigm

In the continuous naming task objects are presented and named in a seemingly random sequence. However, within the sequence different members of semantic categories are presented, separated by 2–8 unrelated objects (Howard et al., 2006). In this task, naming times increase linearly with each new member of the category being named, that is, with the ordinal position of an object within the presented category. This effect is independent of the number of intervening unrelated items (e.g., Belke, 2013; Belke & Stielow, 2013; Costa, Strijkers, Martin, & Thierry, 2009; Howard et al., 2006; Navarrete, Mahon, & Caramazza, 2010; Schnur, 2014).

To account for cumulative interference irrespective of lag length additional learning mechanisms have been proposed (Belke, 2013; Howard et al., 2006; Oppenheim, Dell, & Schwartz, 2010). According to Howard and colleagues (2006), the connection strength between a concept and its lexical entry is enhanced as a consequence of naming. When the next object is named and related concepts, including the previously named category members, are co-activated at the conceptual level, the potential of the latter concepts to activate their lemmas is enhanced. Therefore, these lemmas are stronger competitors than those of previously unnamed objects. As a result, the number of strongly active competitors is steadily increasing with each new member of the category, and cumulative semantic interference is observed. Oppenheim and colleagues (2010) assume that learning not only reinforces the connection of a concept and the selected lemma (referred to as repetition priming) but also weakens the connection weights of co-activated non-target lemmas, comparable with the concept of retrieval-induced forgetting (RIF). They demonstrated that this learning mechanism together with a booster mechanism calibrating the activation of word representations is sufficient to explain cumulative semantic interference without the assumption of lexical selection by competition. Alternatively, Belke (2013) has suggested that cumulative effects originate at the conceptual level in the form of strengthened connections between concepts and their semantic features. These modulations may result in cumulative facilitation effects in semantic classification tasks, as demonstrated by Belke (2013) and Riley, McMahon, and de Zubicaray (2015), reflecting the enhanced activation of shared class features related to the required response (e.g. living–non-living; but see: Wei & Schnur, 2015). However, even though semantic interference in naming tasks might be conceptually mediated and the origin of interference may be conceptual, the locus of interference is still at the lexical level in form of a classic lexical competition effect (please see Belke, 2013, for a detailed discussion). Thus, concerning naming tasks, all model versions predict cumulative semantic interference in the continuous naming task.

The SLN does not explicitly formulate a learning mechanism, but long-lasting effects and modifications of connection strengths can be easily accommodated with the assumption of dynamic and flexible context adaptations of the language production system (Abdel Rahman & Melinger, 2009a, 2009b; see also Abdel Rahman & Melinger, 2011; Rose, Spalek, & Abdel Rahman, 2015). Combining a learning mechanism as either proposed by Howard et al. (2006) or Belke (2013) with the SLN, we predict strong cumulative associative interference because the number of active competitors (the inter-related lexical cohort) is systematically increasing with each newly named member of a given semantic context, resulting in cumulative semantic interference. This should hold in a qualitatively and quantitatively similar way for category members and associates. Specifically, interference for associates should be stronger and more robust in the continuous task compared to the PWI, as described above, or the cyclic blocking paradigm. Even though semantic effects are considered to be long-lasting in the cyclic as well as the continuous paradigm (Belke, 2008, 2013; Belke & Stielow, 2013; Damian & Als, 2005; Navarrete et al., 2012; Navarrete et al., 2014; Schnur, 2014), they differ with regard to experimental factors.

In the cyclic version, the same semantically related stimuli are consecutively and repeatedly presented, while in the continuous paradigm they are (usually) only presented once, and the different members of a given category are separated by intervening unrelated items (cf. Riley et al., 2015; Riès, Karzmark, Navarrete, Knight, & Dronkers, 2015). Assuming lexical competition, the repeated presentation of related stimuli leads to the activation of a lexical cohort and interference. However, it also triggers simultaneously conceptual facilitation and repetition priming (cf. Navarrete et al., 2012, 2014; Oppenheim et al., 2010). Thus, repetitions will have facilitative influences at many processing levels (e.g., stimulus identification, name retrieval, etc.), and homogeneous contexts should trigger conceptual priming concomitant to lexical competition. According to the trade-off assumption, facilitation may dominate in the first naming trials because first, homogeneous contexts should facilitate object identification at the perceptual and conceptual level, resulting in overall facilitation (for behavioral evidence and a similar discussion, please see Abdel Rahman & Melinger, 2007; see also Bar, 2004; Bar & Aminoff, 2003; Crowther & Martin, 2014; Oliva & Torralba, 2007) and because second, the lexical cohorts are not yet fully established. Afterwards identification should be less problematic and homogeneous contexts less helpful. Additionally, the lexical cohorts should be fully established, and therefore competition should dominate the trade-off towards interference. Please note, however, that facilitation in the first cycle is not always found (e.g., Belke et al., 2005; Crowther & Martin, 2014; Damian & Als, 2005; Damian et al., 2001; Schnur et al., 2006),[1] and identification difficulty may be an important factor next to others (cf. Belke & Stielow, 2013; Hocking et al., 2009; Lotto, Job, & Rumiati, 1999; see also Biegler, Crowther, & Martin, 2008; Riès et al., 2015).

Because the present study used the continuous paradigm, we will not go into further detail, but highlight the important differences concerning expected associative interference: Cumulative interference in the continuous naming task should be strong and robust because conceptual activation should be characterized by relatively quickly decaying activation patterns after the naming of a target due to intervening unrelated items (cf. Belke, 2013; Howard et al., 2006), whereas chronical conceptual priming is expected in the cyclic paradigm. Please note that even here unrelated intervening items do not induce cumulative effects (cf. Damian & Als, 2005) probably due to the impact of stimulus repetition, as outlined above. Due to the learning mechanism and the resulting augmented activation levels of previously named competitors, lexical cohort size and therefore interference is cumulatively enhanced with each newly named and related item in the continuous naming task, whereas the cohort and its size is fully established after the first block in the cyclic task.

To summarize, according to the SLN the emergence of an interactive lexical cohort, steadily increasing in size with each ordinal position, in the absence of concomitantly triggered conceptual facilitation should be reflected in robust associatively induced cumulative interference. Consequently, this paradigm is ideal to test the trade-off assumption of the SLN account (Abdel Rahman & Melinger, 2009a, 2009b), and we predict sizeable associative interference relative to those reported in the cyclic version or in the PWI task. However, even though the continuous paradigm sets favorable conditions to observe associative semantic interference, associative and categorical relations may still differ in their capacity to induce the activation of lexical cohorts, as described above. In the present study, since the activity of lexical cohorts depends on the simultaneous activation of semantically inter-related items, we thus selected associatively related stimuli (e.g., microscope, white coat, test tube etc.) with strong thematic associations (e.g., laboratory; Bar, 2004). Several studies have shown that the mere presentation of such stimuli can activate brain structures associated with the representation of the corresponding scheme or context frame (Bar & Aminoff, 2003; Kveraga et al., 2011), including associated concepts. Therefore, lexical cohort activation for these thematically related associates should occur.

[1] For example, Crowther and Martin (2014) employed two different analyses: effects across cycles and slope effects across cycles. Effects across cycles were caracterized by facilitation in the first cycle whereas the slope analyses revealed a linear increase within the first cycle. Apparently, the overall faciliation effect in the first cycle was due to a decrease in RTs between the first and second trial.

2. Experiment 1

In Experiment 1 the picture naming task was preceded by a free association task in which participants were instructed to name all objects they associated with 16 different thematic contexts such as New Year's Eve or Wedding. This was done to enhance the associations of the objects with specific thematic contexts in case these associations might be weaker than the associations between concepts and their categories (cf. Melinger & Abdel Rahman, 2013). We reasoned that awareness for the thematic relations may enhance the expected effects, as shown before (Abdel Rahman & Melinger, 2011).

2.1. Material and methods

2.1.1. Participants

Twenty four subjects, aged 19–40 years ($M = 27.5$, SD = 5.4), were paid for participation in the experiment or received partial fulfillment of a curriculum requirement. All participants were German native speakers and reported normal or correct-to-normal visual accuracy and normal color vision.

2.1.2. Materials

The stimulus set was constructed and tested in a separate pre-study with twelve participants who did not participate in the main experiments. The procedure of this pre-study was based on investigations of the effects of stimuli highly associated with a context (Bar & Aminoff, 2003). A list of 36 themes (e.g., hospital, supermarket, train station etc.) was given to each participant, and they were asked to name – if possible – at least eight concrete objects that they associated with a given theme or context (cf. Bar & Ullman, 1996). An object was considered as typical for a given thematic context when it was named between 4 and 12 times. Then the best 16 themes containing 5 objects that were most frequently named were selected. The resulting stimulus set consisted of 80 objects distributed across 16 themes (cf. Appendix A). For each object a color photograph was selected, scaled to 3.5 × 3.5 cm, and edited for homogeneity of background color. Additionally, 30 pictures of different objects were used as filler stimuli that were presented between target stimuli. Fillers were unrelated to the themes and their associated objects.

24 different lists were created with the constraint that objects belonging to a theme are separated randomly by at least 2 and maximally 8 items (either fillers or targets from other themes) using the program "Mix" (van Casteren & Davis, 2006). Consequently, lag position was randomly allocated (see also Costa et al. 2009). The order of themes and the ordinal position of an item within its thematic context were also randomized in each of the 24 lists. Thus, the design was thus not fully counterbalanced regarding lag and position of items. Moreover, to enhance statistical power and for the case that cumulative interference for associative relations may develop over repetitions (cf. Abdel Rahman & Melinger, 2007, 2011) each participant was presented with 3 different lists constructed in the same way as mentioned above.

2.1.3. Procedure and design

The experiment was performed using Presentation® software (Version 0.70, www.neurobs.com). Participants were seated at a distance of approximately 80 cm in front of a monitor. In a free association task preceding the main naming task, words denoting the 16 themes were presented in random order on the monitor and participants were asked to read the theme aloud and then to name all objects they associated with it. The responses were recorded by the experimenter. Subsequently, the main naming task was conducted. Target pictures were presented on the screen and participants were asked to name each depicted object as fast and accurately as possible.

Each trial began with a fixation cross displayed in the center of a grey screen for 0.5 s. Then a picture was presented for 2 s, followed by a blank screen for 1 s. Naming latencies were measured with a voice key during the entire duration of picture presentation. After the naming response was registered the picture disappeared. Erroneous responses such as wrong naming of objects or stutters were coded by the experimenter.

2.2. Results and discussion

Reaction times (RTs) for correct responses for each ordinal position of an item within the presented theme, collapsed across the

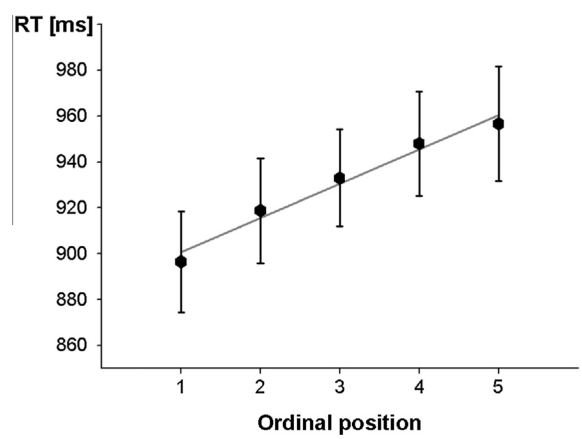

Fig. 1. Naming latencies for each ordinal position in Experiment 1, collapsed across the three presentations. The line represents the slope of the linear trend of the ordinal position effect.

Table 1
Mean naming latencies in milliseconds, mean error rates in percent and the corresponding standard deviations of means for each ordinal position and presentation in Experiment 1.

Presentation	Ordinal position					Mean
	1	2	3	4	5	
Naming latencies						
1	1011 (149)	1000 (145)	1040 (165)	1022 (137)	1046 (138)	1024 (133)
2	843 (114)	904 (130)	904 (102)	926 (141)	935 (136)	903 (122)
3	835 (111)	850 (111)	853 (107)	894 (109)	888 (141)	864 (100)
Mean	896 (107)	918 (111)	933 (103)	948 (111)	956 (122)	
Error rates in%						
1	20.0 (12.3)	19.7 (10.0)	17.7 (11.6)	16.4 (9.5)	16.6 (11.6)	18.1 (6.8)
2	11.7 (10.4)	10.6 (7.9)	10.9 (8.0)	13.8 (10.2)	12.5 (8.4)	11.9 (5.0)
3	12.5 (8.0)	9.6 (8.6)	10.1 (8.4)	9.1 (7.1)	8.0 (8.1)	9.8 (4.9)
Mean	14.7 (6.9)	13.3 (6.3)	12.9 (5.5)	13.1 (5.8)	12.4 (6.1)	

three presentations, are presented in Fig. 1 (see also Table 1). A repeated measures analysis of variance (ANOVA) with the factors ordinal position (5) and presentation (3) with participants (F_1) and themes (F_2) as random variables (cf. Belke & Stielow, 2013; Howard et al., 2006) revealed a main effects of presentation ($F_1(2,46) = 54$, $p < .001$, $\eta_p^2 = .70$; $F_2(2,30) = 130.6$, $p < .001$, $\eta_p^2 = .89$) and ordinal position ($F_1(4,92) = 11.1$, $p < .001$, $\eta_p^2 = .33$; $F_2(4,60) = 7.0$, $p < .001$, $\eta_p^2 = .32$). There was no interaction between presentation and ordinal position, $Fs < 1.7$. For the ordinal position effect, there was a significant linear trend, $F_1(1,23) = 36.6$, $p < .001$, $\eta_p^2 = .62$; $F_2(1,15) = 19.1$, $p < .001$, $\eta_p^2 = .56$, indicating that RTs increased linearly with each ordinal position.

An ANOVA of mean error rates revealed a main effect of presentation (F_1 $(2,46) = 26$, $p < .001$, $\eta_p^2 = .53$; $F_2(1,30) = 30.2$, $p < .001$, $\eta_p^2 = .66$) that reflects a decrease in errors between the first and later presentations (cf. Table 1). No other effects were found, $Fs < 0.8$.

We conclude that associative interference in the cumulative naming paradigm can be observed when the associated objects were pre-activated directly before the naming task.

3. Experiment 2

In Experiment 2 we tested whether the cumulative interference effects for associates found in Experiment 1 were also present when the themes and associated objects were not pre-activated in a free association task prior to the main experiment.

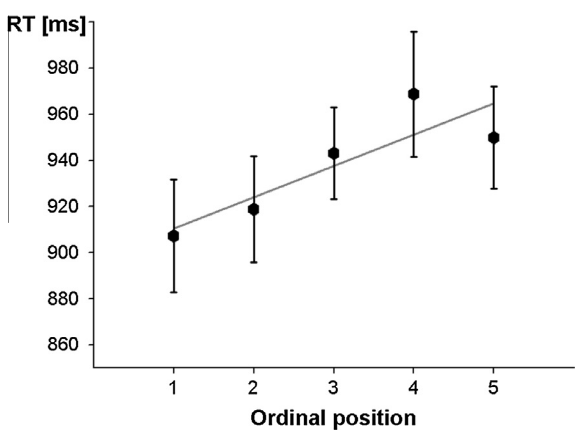

Fig. 2. Naming latencies for each ordinal position in Experiment 2, collapsed across the three presentations. The line represents the slope of the linear trend of the ordinal position effect.

3.1. Material and methods

3.1.1. Participants

Twenty four participants, aged 19–34 years ($M = 25.8$, $SD = 3.8$), were paid for their participation in the experiment or received partial fulfillment of a curriculum requirement. None of the participants took part in Experiment 1 or the pre-study. All participants were native German speakers and had normal or correct-to-normal visual accuracy and normal color vision. Two participants were excluded and replaced because their error rates were twice as high as the average of all participants.

3.1.2. Materials, procedure and design

Stimuli, design and procedure were the same as in Experiment 1 except that here, no free association task was performed prior to the naming task.

3.2. Results and discussion

RTs for each ordinal position, collapsed across the three presentations, are depicted in Fig. 2 (see also Table 2). As in Experiment 1, the ANOVA with the factors ordinal position and presentation revealed significant main effects of presentation ($F_1(2,46) = 97.8$, $p < .001$, $\eta_p^2 = .81$; $F_2(2,30) = 56.8$, $p < .001$, $\eta_p^2 = .79$) and ordinal position ($F_1(4,92) = 12.5$, $p < .001$, $\eta_p^2 = .35$; $F_2(4,60) = 7.3$, $p < .001$, $\eta_p^2 = .32$). The interaction between ordinal position and presentation was not significant, $Fs < 0.5$. There was a significant linear trend for the factor ordinal position, $F_1(1,23) = 40.4$, $p < .001$, $\eta_p^2 = .63$; $F_2(1,15) = 20.6$, $p < .001$, $\eta_p^2 = .57$, suggesting that RTs increased linearly with each ordinal position.

Like in Experiment 1, analysis of errors revealed a main effect of presentation ($F_1(2,46) = 64$, $p < .001$, $\eta_p^2 = .74$; $F_2(1,30) = 37.3$, $p < .001$, $\eta_p^2 = .71$) reflecting a decrease in errors between the first and last presentations (Table 2). No other effects reached significance, $Fs < 0.9$.

Irrespective of whether the thematic contexts and associated items were pre-activated (as done in Experiment 1) or not (Experiment 2), sizable cumulative semantic interference effects were observed, suggesting, as hypothesized, strong interference due to the accumulation of active category members at the lexical level. However, more critically, one may argue that the stimulus set partly contained categorical relations within themes. The potential influence of mixed categorical and thematic relations was tested in Experiment 3.

Table 2
Mean naming latencies in milliseconds, mean error rates in percent and the corresponding standard deviations of means for each ordinal position and presentation in Experiment 2.

Presentation	Ordinal position					Mean
	1	2	3	4	5	
Naming latencies						
1	988 (128)	993 (108)	1025 (113)	1057 (146)	1024 (121)	1024 (105)
2	875 (137)	893 (134)	895 (106)	939 (149)	927 (138)	903 (119)
3	858 (125)	869 (129)	908 (115)	909 (146)	897 (119)	864 (116)
Mean	907 (119)	918 (112)	943 (97)	968 (132)	949 (108)	
Error rates in%						
1	20.3 (12.3)	17.4 (10.0)	19.5 (11.6)	18.7 (9.5)	16.1 (11.6)	18.4 (6.0)
2	9.6 (10.4)	12.7 (7.9)	12.2 (8.0)	13.0 (10.2)	11.9 (8.4)	11.9 (4.9)
3	8.3 (8.0)	9.6 (8.6)	8.8 (8.4)	11.7 (7.1)	10.1 (8.1)	9.7 (3.9)
Mean	12.7 (5.9)	13.2 (6.2)	13.5 (5.5)	14.4 (6.7)	12.7 (7.2)	

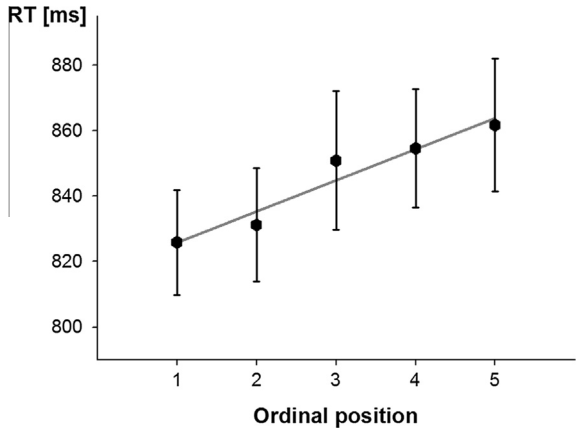

Fig. 3. Naming latencies for each ordinal position in Experiment 3, collapsed across the three presentations. The line represents the slope of the linear trend of the ordinal position effect.

4. Experiment 3

A major factor for the emergence of semantic interference is the simultaneous activation of interrelated items. Therefore we selected objects that are highly associated with a thematic context, since several studies have shown that the mere presentation of such objects automatically induces the activation of thematically related concepts (Bar & Aminoff, 2003). As described in the Method section of Experiment 1, we constructed the stimulus set by asking participants in a pre-study to name objects that they typically associated with a theme. However, this procedure, and the explicit focus on thematic associations may not have prevented categorical relations between some objects of the themes. For example, the objects tank and jet fighter may be considered not only as members of the military theme but also as members of the category "means of transportation" (cf. Appendix A). Even though such categorical links are unsystematic and may not induce strong and consistent effects as the ones found here, such influences of categorical relations cannot be ruled out entirely. Therefore, we reconstructed the stimulus set in Experiment 3 and took care to strictly avoid any semantic relations between objects of the themes that may be viewed as categorical.

4.1. Material and methods

4.1.1. Participants

Twenty four participants, aged 18–38 years ($M = 23.5$, SD = 5.8), were paid for their participation in the experiment or received partial fulfillment of a curriculum requirement. None of the participants took part in Experiments 1, 2 or the pre-studies described below. All participants were native German speakers and had normal or correct-to-normal visual accuracy and normal color vision. Two participants were excluded due to poor naming performance in the form of error rates twice as large as the average of all participants.

4.1.2. Materials

The stimulus set used in Experiments 1 and 2 was evaluated and modified in two pre-studies. First, after having been introduced to the distinction between categorical relations (objects sharing a semantic category and specific features) and associative/thematic relations (object from different categories with non-overlapping semantic features that belong to a common thematic context), fifteen participants, read all objects from each theme and named all objects that were, in their view, categorically related. We also included different sets of 5 natural objects that were either categorically related or completely unrelated to prevent any response strategies. Indeed, categorical relations were identified between 20.3% (min: 0%; max: 58.7%) of the objects, $t(15) = 4.8$, $p < 0.001$. Based on these results, we replaced the problematic objects by new ones that were (even though in some cases less strongly) associatively related to the respective theme (e.g., jet fighter was replaced by sickbay in the military theme). We also excluded 2 entire thematic sets (astronautics and casino) because we failed to find objects without any categorical links to the remaining ones. Instead, we included a new set circus that was included but not selected in the pre-study of Experiment 1. The reconstructed stimulus set was once again tested. The rate of objects classified as category members dropped to 4.1%, and this effect was statistically not reliable, $t(14) = 1.3$, $p > 0.05$. The new stimulus set consisted of 75 objects distributed across 15 themes (cf. Appendix B). 26 pictures of different objects were used as filler stimuli that were presented between target stimuli. Care was taken that fillers did not have categorical or associative relations with objects of the thematic sets.

4.1.3. Procedure and design

Design and procedure were the same as in Experiment 2. Like in Experiment 2, themes were not pre-activated in a free association task prior to the main experiment.

4.2. Results

As in Experiments 1 and 2, the ANOVA with the factors ordinal position and presentation revealed significant main effects of presentation ($F_1(2,46) = 76.1$, $p < .001$, $\eta_p^2 = .76$; $F_2(2,28) = 92.2$, $p < .001$, $\eta_p^2 = .86$) and ordinal position ($F_1(4,92) = 3.6$, $p < .01$,

Table 3
Mean naming latencies in milliseconds, mean error rates in percent and the corresponding standard deviations of means for each ordinal position and presentation in Experiment 3.

Presentation	Ordinal position					Mean
	1	2	3	4	5	
Naming latencies						
1	935 (115)	923 (106)	946 (129)	938 (113)	956 (119)	1024 (90)
2	793 (91)	807 (88)	814 (117)	830 (116)	834 (116)	903 (92)
3	748 (94)	762 (102)	792 (113)	794 (96)	793 (130)	864 (95)
Mean	825 (78)	831 (84)	850 (103)	854 (88)	861 (98)	
Error rates in%						
1	18.0 (10.3)	15.8 (9.9)	15.5 (6.9)	15.0 (10.4)	11.1 (7.7)	15.1 (4.4)
2	11.1 (8.4)	11.6 (9.6)	9.7 (7.8)	10.5 (8.5)	9.4 (6.1)	10.5 (4.0)
3	10.8 (7.8)	11.1 (6.9)	11.1 (8.9)	6.6 (6.2)	8.6 (9.3)	9.6 (4.3)
Mean	13.3 (4.8)	12.8 (5.3)	12.1 (5.8)	10.7 (4.8)	9.7 (5.3)	

$\eta_p^2 = .14$; $F_2(4,56) = 4.2$, $p < .01$, $\eta_p^2 = .23$). RTs for each ordinal position, collapsed across the three presentations, are depicted in Fig. 3 (see also Table 3). The interaction between ordinal position and presentation was not significant, $Fs < 0.5$. There was a significant linear trend for the factor ordinal position, $F_1(1,23) = 18.6$, $p < .001$, $\eta_p^2 = .44$; $F_2(1,14) = 17.7$, $p = .001$, $\eta_p^2 = .56$, suggesting a linear increase in RTs with each named member of a thematic context.

Analysis of errors revealed a main effect of presentation ($F_1(2,46) = 18.7$, $p < .001$, $\eta_p^2 = .44$; $F_2(2,28) = 27.6$, $p < .001$, $\eta_p^2 = .66$). Error rate decreased between the first and last presentations (Table 3). No other effects reached significance, $Fs < 2.0$.

5. Discussion

The results of the present study are clear-cut. Three experiments employing the continuous version of the semantic blocking paradigm revealed robust cumulative semantic interference for associative relations. As demonstrated for categorical relations in this paradigm, we observed a linear increase of naming times with each newly named object belonging to a given theme. These findings demonstrate that the presentation of objects that are associated within a thematic context causes an accumulation of semantic interference in a similar way as demonstrated for categorical relations. According to the SLN (Abdel Rahman & Melinger, 2009a, 2009b) lexical competition between associates is typically weak and hidden by concomitant conceptual facilitation because semantic activation spread between associates does not result in lexical cohort activation due to low semantic feature overlap. In contrast, the continuous naming paradigm was predicted to reveal associative interference because the proportion of conceptual facilitation should be small and relatively constant, whereas lexical cohort activation should be continuously enhanced, resulting in a linear increase of RTs (see above).

Interestingly, the cumulative interference is seemingly independent of the pre-activation of the associations between objects and themes before the naming task, and similar effect magnitudes can be observed in Experiments 1 (with associative pre-activation) and 2 (without pre-activation). This impression was confirmed by an additional analysis with the factors ordinal position, presentation, and the between-subjects factor experiment, revealing effects of presentation ($F_1(2,46) = 147.5$, $p < .001$, $\eta_p^2 = .86$; $F_2(2,30) = 120.7$, $p < .001$, $\eta_p^2 = .88$) and ordinal position ($F_1(4,92) = 22.8$, $p < .001$, $\eta_p^2 = .49$; $F_2(4,60) = 13$, $p < .001$, $\eta_p^2 = .46$), but no main effect and no interactions with the factor experiment ($F_{1/2} < 1.2$). Here again, the effect of ordinal position was characterized by a significant linear trend, $F_1(1,23) = 70.1$, $p < .001$, $\eta_p^2 = .75$; $F_2(1,15) = 34$, $p < .001$, $\eta_p^2 = .69$. We conclude that the pre-activation of associative relations has no influence on the cumulative associative interference observed here. Thus, even though the objects are separated by different unrelated objects, their co-occurrence in an experimental sequence is sufficient to form a coherent and strong thematic activation pattern (cf. Bar, 2004; Bar & Aminoff, 2003; Kveraga et al., 2011).

In general, the magnitude of the overall cumulative effects for associative relations across all experiments is relatively large. Irrespective of the pre-activation of associates or the specific stimulus materials naming was slowed with each new member of a thematic context by about 13.2 ms on average (Experiment 1: 15 ms (95% CI ± 5.6); Experiment 2: 14.7 ms (95% CI ± 5.4); Experiment 3: 9.9 ms (95% CI ± 5.2)). This average increase of RTs for each ordinal position is comparable to the reports for categorical effects in the literature. For instance, Belke and Stielow (2013) and Costa et al. (2009) reported 12 ms, Belke (2013) 20 ms, and Howard et al. (2006) the largest increase with 30 ms. Thus, as predicted by the SLN, the continuous naming task can reveal associative interference better than other semantic context paradigms. Moreover, in contrast to the relatively small traces of associative interference found in the PWI and cyclic blocking paradigm (Abdel Rahman & Melinger, 2007; Melinger & Abdel Rahman, 2013), the effects do not seem to be smaller than cumulative categorical effects and are also not influenced by the repetition of lists (Costa et al., 2009; Navarrete et al., 2010) like, for example, in the cyclic paradigm (cf. Abdel Rahman & Melinger, 2007). This is a direct consequence of the mechanisms underlying the cumulative increase in RTs. Assuming that the activation spread at the conceptual level is not chronical due to direct consecutive presentations of related stimuli in blocks, that the resulting converging activation of lexical representations is similar, and assuming that the learning mechanism is identical for associative and categorical relations, the magnitude of the linear increase in RTs should be comparable for associative and categorical relations (cf. Section 1).

Moreover, the similarity of interference effects for partially mixed categorical/ associative (Experiment 2) and pure associative relations (Experiment 3) is revealing, and can also be confirmed by an additional analysis with the factors ordinal position, presentation, and the between-subjects factor experiment, revealing a significant main effect of presentation ($F_1(2,46) = 112.5$, $p < .001$, $\eta_p^2 = .83$; $F_2(2,26) = 85.4$, $p < .001$, $\eta_p^2 = .86$) and ordinal position ($F_1(4,92) = 12.6$, $p < .001$, $\eta_p^2 = .35$; $F_2(4,52) = 12$, $p < .001$, $\eta_p^2 = .48$), but also an effect of experiment ($F_1(1,23) = 13.4$, $p < .001$, $\eta_p^2 = .36$; $F_2(1,13) = 49$, $p < .001$, $\eta_p^2 = .79$), and an interaction between experiment and presentation ($F_1(2,46) = 3.6$, $p < .05$, $\eta_p^2 = .13$; $F_2(2,26) = 3.6$, $p < .05$, $\eta_p^2 = .21$) which might be due to the different stimulus materials used in Experiments 2 and 3. More importantly, there was no interaction of ordinal position and experiment. Thus, Experiment 3 demonstrates that categorical relations do not significantly contribute to the associative–thematic interference observed here, and that the accumulation of semantic interference is mainly due to the thematic associations. Even though replacing some of the categorically related objects in the stimulus set of Experiment 3 may have reduced the associative strength, this did not affect the linear increase of interference. The similarity of categorical and associative effects and the observation that categorical links do not significantly change associative interference underline the idea that observed differences between associative and categorical context effects, for instance, in the PWI paradigm, are more likely due to the choice of paradigm than due to principal differences between associative and categorical relations (cf. Jackson, Hoffman, Pobric, & Ralph, 2015), and that associative and categorical relations exert the same impact on lexical retrieval processes with quantitative differences concerning the relative contributions of conceptual and lexical effects.

One might still argue that categorical relations between objects of different thematic sets (e.g., bee (apiary), worm (fishing), cow (farm)) could have influenced the observed effects. However, this is highly unlikely because the order of themes and the ordinal position of an item within the theme were randomized for each constructed list. Therefore, the few unsystematic categorical links between objects of different themes should not yield a comparable (and sizeable) linear increase of RTs with ordinal position in three independent experiments. Moreover, Alario and del Prado Martin (2010) investigated whether the ordinal position effect between members of one semantic category (e.g. zoo animals) is affected when the same members can be regrouped into other categories also used in the experiment (e.g., cow (farm animals) and elephant (zoo animals)). They did not find a modulation of the linear increase of semantic interference by categorical relations across sets. Hence, the most plausible explanation for our results, as outlined above, is that the accumulation of semantic interference is mainly due to the thematic associations.

5.1. Implications for language production models

Thus far, we have focused on models incorporating lexical competition, and specifically on the SLN account that directly predicts the emergence of more robust associative interference in the continuous naming task compared to the PWI and the cyclic paradigm. We now turn to a discussion of the present findings in light of alternative models that dismiss the assumption of lexical competition.

The reported findings can also be explained by the non-competitive incremental learning model by Oppenheim and colleagues (2010), assuming that a learning mechanism that includes not only strengthened links between concept and lemmas upon naming, but also weakened links between co-activated non-target concepts and their lemmas in the form of RIF. Even though to date neurophysiological evidence in support of the proposed mechanisms during language production is still scant (de Zubicaray, McMahon, & Howard, 2013; Riès et al., 2015; Vieth, McMahon, Cunnington, & de Zubicaray, 2015), this model clearly provides an alternative non-competitive account for cumulative interference, including the present results.

Concerning cyclic blocking, Oppenheim et al. (2010) also assume a learning mechanism that results in cumulative interference of the same size within all homogeneous blocks, and additionally repetition priming between blocks. Cyclic interference is thus explained as a result of the interplay between learning including RIF and repetition priming. However, Navarrete and colleagues (2014) have recently reported cumulative facilitation, rather than interference, in homogeneous blocks in a paradigm in which direct repetition priming was avoided. This effect cannot completely be accounted for by the model of Oppenheim and colleagues (2010). Navarrete et al. (2014) conclude that the default polarity of semantic context effects in the blocked naming paradigm is facilitation, rather than interference, and that observed interference actually reflects less repetition priming in related compared to unrelated blocks (Navarrete et al., 2014; see also: Navarrete et al., 2012). Yet, cumulative facilitation is opposite to a recent report by Crowther and Martin (2014), reporting cumulative interference also in first blocks that is reduced in following cycles, due to cognitive control factors.[2]

In general, and as discussed above, facilitatory effects, including cumulative and non-cumulative facilitation in first naming trials in the cyclic blocking paradigm, are in line with lexical competition models assuming semantic context effects both at the conceptual and at the lexical level (Abdel Rahman & Melinger, 2009a, 2009b; Belke & Stielow, 2013; Roelofs & Piai, 2015). For instance, initial facilitation in the cyclic blocking paradigm can also be taken as evidence for facilitated perceptual and conceptual stages of object identification due to semantic contexts, as discussed in the introduction (e.g., Abdel Rahman & Melinger, 2007; Bar, 2004; Oliva & Torralba, 2007). For other facilitation effects the empirical evidence is very heterogeneous. While Mahon and colleagues (2007) report faster naming in semantically close relative to distant semantic contexts, other authors (Aristei & Abdel Rahman, 2013; Hutson & Damian, 2014; Rose & Abdel Rahman, submitted for publication; Vieth, McMahon, & de Zubicaray, 2014a; Vigliocco et al., 2002) report null effects or the opposite pattern. Likewise, for part–whole relations facilitation (Costa et al., 2005) and interference (Sailor & Brooks, 2014; Vieth et al., 2014b, 2015) has been reported. Because this is not directly relevant for the present purpose, we will not further discuss these effects.

While the model of Oppenheim and colleagues can account for semantic interference in the continuous and cyclic naming paradigm, it cannot be applied to explain semantic interference in the PWI task. For effects of word distractors, the response exclusion account has been proposed by Mahon and colleagues (2007), assuming that all semantic relations induce facilitation due to semantic priming, and that interference only arises when distractors share response relevant criteria with the target (shared category membership), thus blocking the articulatory output buffer, which then have to be removed before target articulation. This model was proposed to account for distractor effects and is not applicable to findings in the continuous or cyclic naming paradigm.

We would like to stress here that in our view lexical competition models, including the SLN account, have the advantage of providing a comprehensive and simple theoretical framework that can parsimoniously explain context induced semantic facilitation and interference effects in many language production paradigms such as PWI, cyclic and continuous naming tasks (Abdel Rahman & Melinger, 2009b; Belke & Stielow, 2013; Belke et al., 2005; Piai, Roelofs, & Schriefers, 2012; Roelofs & Piai, 2015; Roelofs, Piai, & Schriefers, 2011). Incorporating different cognitive sub-processes associated with the different paradigms (e.g., additional learning mechanisms or top-down bias; cf. Belke, 2013; Belke & Stielow, 2013; Howard et al., 2006), this framework generates predictions across paradigms, helping us to understand why, as shown here for instance, associative interference is hardly observable in the PWI task whereas traces can be found in the cyclic paradigm and in the continuous naming task it is a robust phenomenon. Thus, even though we may not be able to cover all evidence available on semantic context effects, as for example in language comprehension (cf. Wei & Schnur, 2015), and current or future research may also reveal contrasting evidence to certain degrees (Bormann, 2011; de Zubicaray et al., 2014; Sailor & Brooke, 2014), we assume that lexical competition is still a viable mechanism to explain language production phenomena.

5.2. Conclusion

We conclude that the observed robust cumulative associative interference is in line with competitive and non-competitive models of language production, and that the simplest account in our view is the assumption of lexical competition that is detectable when conceptual facilitation is comparatively weak while lexical competition is augmented by the cumulative activation of an interactive lexical cohort, as directly predicted by the SLN. The present findings underscore the relevance of non-categorical semantic relations for conceptual and lexical processes during language production that deserve more empirical attention.

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[2] Indeed, recent studies suggest that an additional difference between the cyclic and the continuous paradigm is the involvement of top-down control mechanisms. In cyclic blocking participants are able to memorize the task set (e.g., animals: cat, dog, cow, etc.) after the first presentation. Thus, accumulation of semantic interference may be modulated by top-down mechanisms that bias semantic–lexical activation toward task-relevant and presented, and against task-irrelevant and absent, representations (Belke, 2008; Belke & Stielow, 2013; see also: Biegler et al., 2008; Crowther & Martin, 2014; Riès et al., 2015; Schnur et al., 2006; Vieth et al., 2015). However, in terms of the SLN, this top-down mechanism would also promote conceptual activation levels of task-relevant representations and reduce activation of a potentially bigger lexical cohort. Thus, even though lexical competition effects still surpass concomitant facilitation, they will not linearly increase.

Appendix A. Themes and objects presented in Experiments 1 and 2

Theme	Object				
	1	2	3	4	5
Silvester (New Year's Eve)	Sekt (champagne)	Feuerwerk (firework)	Wunderkerze (sparkler)	Luftschlange (streamer)	Bleigießen (lead-pouring)
Fußball (soccer)	Fußball (soccer ball)	Tor (goal)	Stadion (stadium)	Pfeife (whistle)	Trikot (tricot)
Militär (military)	Panzer (tank)	Granate (grenade)	Gewehr (rifle)	Uniform (uniform)	Kampfjet (jet fighter)
Büro (office)	Computer (computer)	Bürostuhl (office chair)	Ordner (folder)	Tacker (stapler)	Telefon (telephone)
Baby (baby)	Kinderwagen (buggy)	Schnuller (pacifier)	Windel (diaper)	Strampelanzug (playsuit)	Wiege (baby cradle)
Labor (laboratory)	Reagenzglas (test tube)	Schutzbrille (safety glasses)	Mikroskop (microscope)	Kittel (white coat)	Bunsenbrenner (Bunsen burner)
Raumfahrt (astronautics)	Rakete (rocket)	Raumstation (space platform)	Satellit (satellite)	Astronaut (astronaut)	Mond (moon)
Bahnhof (train station)	Zug (train)	Schaffner (train guard)	Gleis (rail)	Anzeigetafel (destination board)	Fahrkartenautomat (ticket machine)
Morgenroutine (morning routine)	Wecker (alarm clock)	Bett (bed)	Zahnbürste (toothbrush)	Dusche (shower)	Müsli (cereal)
Weihnachten (Christmas)	Geschenke (presents)	Weihnachtsbaum (Christmas tree)	Krippe (manger)	Plätzchen (cookies)	Adventskranz (Advent wreath)
Imkerei (apiary)	Biene (bee)	Honig (honey)	Imkeranzug (apiarist suit)	Wabe (comb)	Bienenstock (beehive)
Fischen (fishing)	Angel (fishing rod)	Boot (boat)	Eimer (bucket)	Haken (hook)	Wurm (worm)
Hochzeit (wedding)	Ring (ring)	Torte (cake)	Brautkleid (wedding dress)	Blumenstrauß (bouquet)	Kirche (church)
Casino (casino)	Chips (gambling tokens)	Spielautomat (gaming machine)	Roulette (roulette)	Würfel (dice)	Geld (money)
Bauernhof (farm)	Kuh (cow)	Traktor (tractor)	Stall (stable)	Mistgabel (pitchfork)	Heuballen (hay bale)
Urlaub (holidays)	Strand (beach)	Flugzeug (plane)	Sonnenbrille (sun glasses)	Koffer (suitcase)	Bikini (bikini)
Filler	Akkordeon (accordion), Blatt (sheet), Brust (breast), CD (CD), Champignon (button mushroom), Dose (box), Eiffelturm (Eiffel Tower), Fenster (window), Freiheitsstatue (Statue of Liberty), Garn (yarn), Gitarre (guitar), Glühbirne (light bulb), Handy (mobile phone), Heizung (heating), Joystick (joystick), Nashorn (rhino), Pfandkasten (reusable box), Pfanne (pan), Schlüssel (key), Staffelei (easel), Tafel (panel), Teppich (carpet), Thron (throne), Tür (door), Turm (tower), Tuschkasten (paintbox), Wasserfall (waterfall), Wirbelsäule (spinal column), Zelt (tent), Zunge (tongue)				

Appendix B. Themes and objects presented in Experiment 3

Theme	Object				
	1	2	3	4	5
Silvester (New Year's Eve)	Sekt (champagne)	Feuerwerk (firework)	Raclette (raclette grill)*	Luftschlange (streamer)	Bleigießen (lead-pouring)
Fußball (soccer)	Fußball (soccer ball)	Pokal (cup)*	Stadion (stadium)	Pfeife (whistle)	Trikot (tricot)
Militär (military)	Hubschrauber (helicopter)*	Funkgerät (radio device)*	Gewehr (rifle)	Uniform (uniform)	Lazarett (sickbay)*
Büro (office)	Computer (computer)	Bürostuhl (office chair)	Ordner (folder)	Briefmarke (stamp)*	Whiteboard (whiteboard)*
Baby (baby)	Kinderwagen (buggy)	Schnuller (pacifier)	Windel (diaper)	Mobile (crib mobile)*	Babybrei (baby pap)*
Labor (laboratory)	Periodensystem (period ic table)*	Schutzbrille (safety glasses)	Mikroskop (microscope)	Zelle (cell)*	Chemikalien (chemicals)*

Appendix B (*continued*)

Theme	Object				
	1	2	3	4	5
Bahnhof (train station)	Zug (train)	Schaffner (train guard)	Gleis (rail)	Anzeigetafel (destination board)	Fahrkartenautomat (ticket machine)
Morgenroutine (morning routine)	Wecker (alarm clock)	Bett (bed)	Zahnbürste (toothbrush)	Zeitung (newspaper)*	Müsli (cereal)
Weihnachten (Christmas)	Geschenke (presents)	Weihnachtsbaum (Christmas tree)	Schlitten (sled)*	Plätzchen (cookies)	Adventskranz (Advent wreath)
Imkerei (apiary)	Biene (bee)	Honig (honey)	Imkeranzug (apiarist suit)	Pollen (pollen)*	Bienenstock (beehive)
Fischen (fishing)	Angel (fishing rod)	Boot (boat)	See (lake)*	Gummistiefel (gumboot)*	Wurm (worm)
Hochzeit (wedding)	Ring (ring)	Torte (cake)	Brautkleid (wedding dress)	Blumenstrauß (bouquet)	Kirche (church)
Bauernhof (farm)	Kuh (cow)	Traktor (tractor)	Stall (stable)	Tränke (drinking trough)*	Heuballen (hay bale)
Urlaub (holidays)	Strand (beach)	Flugzeug (plane)	Sonnencreme (sunblocker)	Koffer (suitcase)	Bikini (bikini)
Zirkus (circus)	Clown (clown)*	Manege (circus ring)*	Zuckerwatte (cotton candy)*	Jonglierkeule (juggling club)*	Elefant (elephant)*
Filler	Aschenbecher (ash tray)*, Blatt (sheet), Brust (breast), Dose (box), Feder (feather)*, Garn (yarn), Gitarre (guitar), Glühbirne (light bulb), Heizung (heating), Holz (wood)*, Käfig (cage)*, Joystick (joystick), Kasse (checkout counter)*, Parfum (perfum), Pumpe (pump)*, Reißverschluss (zipper), Schalter (button)*, Schlüssel (key), Schultüte (switch)*, Sparschwein (piggybank)*, Staffelei (easel), Telefonzelle (callbox)*, Kran (crane)*, Tuschkasten (paintbox), Wanderstock (hiking pole)*, Würfel (dice)*				

* New objects.

Appendix C. Supplementary material

Supplementary data associated with this article can be found, in the online version, at http://dx.doi.org/10.1016/j.cognition.2016.03.013.

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