Digits vs. Pictures: The influence of stimulus type on language switching.

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The authors would like to thank David W. Green, Susan C. Bobb and one anonymous reviewer for helpful comments on an earlier version of this article.

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Key words: Bilingualism, language control, language switching, digit naming, picture naming

Abstract

Stimuli used in cued language switching studies typically consist of digits or pictures. However, the comparability between both stimulus types remains unclear. In the present study, we directly compared digit and picture naming in a German-English language switching experiment. Because digits represent a semantic group and contain many cognates, the experiment consisted of four conditions with different stimulus sets in each condition: Digits, standard language switching pictures, pictures depicting cognates, and semantically-related pictures. Digit naming caused smaller switch costs than picture naming. The data suggests that this difference can be attributed to phonology. Both methodological and theoretical implications are discussed.

(100 words)

Numerous factors influence bilingual speech production, be it prior exposure to a syntactic structure (Loebell & Bock, 2003), distracter-words or pictures (Ehri & Rayn, 1980) or even the word type that is being produced, such as cognates (words with a similar etymological background in two or more languages, which often co-occur with a large phonological overlap; Costa, Caramazza & Sebastian-Galles, 2000; Hoshino & Kroll, 2008) or homophones (words with a similar pronunciation, but different meaning in two languages; Schulpen, Dijkstra, Schriefers & Haspers, 2003). Thus it appears very likely that such factors as the word or stimulus type also influence bilingual language production when subjects switch between two languages. In the present study we set out to investigate the influence of stimulus type on bilingual speech production in language switching by testing the distinctive influence of two stimulus types during bilingual naming: digits and pictures. Exploring the influence of stimulus types on language switching is interesting both on an empirical and theoretical level. Empirically, it might inform us about the comparability of language switching studies that use different stimulus materials. On a theoretical level, we believe that stimulus effects on language switching times can indicate which aspects of word production (e.g., semantics, phonology) are critical in language switching.

In language switching, the cognitive processes involved during bilingual language production are investigated by examining the performance difference between trials in which the language was repeated with respect to the previous trial (repetition trials) and trials in which the language was switched with respect to the previous trial (switch trials). Typically it is harder to switch to a language than to repeat the same language (“switch costs”; e.g., Meuter & Allport, 1999; Philipp, Gade & Koch, 2007). These switch costs are a marker for the cognitive control needed to produce one of the two languages (e.g., Christoffels, Firk & Schiller, 2007; Green, 1998). Furthermore, switch costs are often asymmetric across languages, with larger switch costs going to L1 than going to L2 (e.g., Meuter & Allport, 1999; see also Koch, Gade, Schuch & Philipp, 2010, for a review of relevant task switching studies).

The studies discussed above used different types of stimuli: pictures (e.g., Costa, Santesteban & Ivanova, 2006; Hernandez & Kohnert, 1999; Verhoef, Roelofs & Chwilla, 2010); digits (e.g., Campbell, 2005; Meuter & Allport, 1999; Philipp, Gade & Koch, 2007). Irrespective of the type of stimuli, all language switching studies report switch costs. Importantly though, while the size of these switch costs differed between studies, it is hard to evaluate differences between previous digit naming and picture naming language switching studies due to the many methodological differences that go beyond the stimulus differences. First, there is a large diversity in task preparation time (e.g., manipulations of cue-to-stimulus interval, CSI) across different language switching studies (for a review of preparation effects in task switching, see, e.g., Kiesel et al., 2010). Furthermore, over previous language switching studies there is an inconsistent effect of preparation time. For example, Costa and Santesteban (2004) tested highly proficient bilinguals in a language switching setting and found a reduction of language switch costs with a long CSI (see also Verhoef, Roelofs & Chwilla, 2009). Philipp, Gade and Koch (2007), on the other hand, found a reversed preparation effect in a study that investigated L1/L2, L2/L3 and L1/L3 language switching. These studies already illustrate two other important differences between studies: The languages that are used and the language proficiency of the participants. Whereas the proficiency of the participants mainly seems to influence the symmetry vs. asymmetry of language switch costs (Costa & Santestaben, 2004), it was found that language pairing can influence both the size of switch costs (Philipp et al., 2007) and the (a)symmetry of switch costs (Costa et al., 2006). Due to all these differences between studies, the direct comparison of individual language switching studies is problematic. Therefore, in the present study, we aimed at comparing the influence of stimulus type (digits vs. pictures) within participants.

While there are similarities between pictures and digits, for example both provide no cue on how to pronounce the concept, they do differ on a variety of levels. First, digits represent an abstract concept, namely quantity, whereas pictures represent concrete objects. A consequence of this difference is that the actual representation of digits is arbitrarily mapped to their meaning, which is not the case for pictures.

A second difference is that digits represent a specific semantic group (e.g., Cappelletti, Warrington, & Butterworth, 1995; Herrera & Macizo, 2010, 2011), which is not the case for all picture sets. Related to this is the question of whether digit and picture naming involves the activation of semantic information. While it is generally agreed that picture naming involves activation of semantic information (Glaser & Düngelhoff, 1984; Smith & Magee, 1980), there is no conclusive evidence as to whether digit naming requires activation of semantic information. One finding in favor of semantic activation during digit naming is the numerical distance effect, which consists of a facilitation effect when the current digit has a small numerical distance to the prior digit (e.g., Brysbaert, 1995). However, recent studies on semantic blocking showed that digit naming does not involve semantic activation (Herrera & Macizo, 2010, 2011). In the semantic blocking paradigm, pure blocks, which contain items that are semantically-related to each other, are contrasted against mixed blocks, which contain items from different semantic groups that are presented in a random order. The results showed that picture naming is slower during pure blocks than during mixed blocks. The interference effect found during pure blocks is assumed to be caused by the continued activation in the same semantic group, which produces co-activation of semantically-related items and causes response competition among these items. However, in contrast to picture naming, for digit naming and number-word naming the data showed a facilitation effect in the pure block condition. This implies that digit naming does not require activation of semantic information. Similar results have been found with a Stroop-like paradigm (Roelofs, 2006).

Another difference between digit and picture naming is that in languages from the same language family (e.g., Romance languages or Germanic languages), as in the present study (German-English), many digits are cognates. Cognates are known to cause faster production during picture naming (e.g., Costa, Caramazza & Sebastian-Galles, 2000; Hoshino & Kroll, 2008). This effect has been used as an indication of phonological cross-language activation, suggesting that both languages are simultaneously activated. For example, in the study of Hoshino and Kroll (2008) subjects (Japanese-English) had to name pictures in their second language. When the pictures depicted cognates they were named faster than when they depicted non-cognates. As the facilitation effect was present across different scripts, it can be concluded that there is phonological cross-language activation with languages that use different scripts.

Finally, there is a methodological difference between digit and picture naming language switching studies. Generally language switching studies that employ pictures use unique stimuli for each trial, while language switching studies that implement digits typically use digits 1-9 throughout the experiment. Prior co-occurrence of a task, and probably of a language, with a certain stimulus influences the current trial (Allport & Wylie, 2000; Arrington, Weaver & Pauker, 2010; Koch & Allport, 2006; Waszak, Hommel, & Allport, 2003; for a review see Kiesel et al., 2010). For example, Waszak, Hommel and Allport (2003) used picture-word Stroop stimuli to investigate stimulus-based priming of tasks. Their results showed that item-specific priming effects on switch trials occurred after a single prior exposure of the stimulus with the task and with over 200 trials between prime and probe trial.

Given this background, the main goal of the present study was to investigate if there are switch cost differences, with respect to voice-onset time, due to different stimulus types: pictures or digits. To this end, we used German-English cued language switching and manipulated the sets of to-be-named stimuli across blocks. That is, we presented in “pure” blocks either a set of digits or a set of pictures, which are typically used during language switching studies (standard picture stimulus set). Additionally, two other picture control stimulus sets were implemented to investigate the influence of certain digit characteristics. In this respect we added a control stimulus set during which the participants had to name pictures that had a semantic relationship with each other. By adding this characteristic to a picture set, the items of this set should interfere with naming of one another, as has been shown by the semantic blocking paradigm (e.g., Herrera & Macizo, 2010, 2011; Kroll & Stewart, 1994). Another digit characteristic was the cognate status or large phonological overlap within digits and between languages. To control for this, we added a second picture control stimulus set in which the pictures depicted cognates with a large within-item phonological overlap between languages. This characteristic should impose co-activation of competing languages and result in a within-item response-related influence. Finally, to account for stimulus-based priming of the languages, each condition contained an equal amount of nine stimuli.

Since not all contrasts are within the scope of this study, we investigated three pre-planned contrasts. First, we planned on comparing digit naming with standard picture naming to establish the basic phenomenon. In this contrast, we expected switch cost differences between the stimulus sets owing to large differences between them (we refer to the potential difference as the digit effect). Additionally, we compared digit naming with both control stimulus sets to explore the origin of the digit effect during bilingual language switching. By exploring whether the digit effect also occurs in the comparisons between either digits and cognates and between digits and semantically-related items, we can further specify whether the digit effect is influenced by digits being cognates and/or a single semantic group.

Method

Participants

Twenty-four native Germans (18 female, mean age = 23), who had at least seven years of formal English education (mean = 8.3), participated. The average self-rated score of English spoken production, out of seven, was 4.9. Half of the participants were paid (4€), while the other half received partial course credit.

Material

During the present study nine unique items were presented in each of the four stimulus sets. The four stimulus sets were presented in pure stimulus set blocks and consisted of a digit stimulus set (1-9), a standard picture stimulus set (e.g., Stadt/city), a cognate control stimulus set (e.g., Ball/ball) and a control stimulus set with semantically-related items (e.g., Bein/leg) (see appendix for the entire list of stimuli). The semantic control stimulus set comprised items principally related to the human body. The overlap between picture stimulus sets was kept to a minimum, as there were no cognates or items with a large phonological overlap between languages in the standard picture and semantic control stimulus set and there were no obvious semantic relations between the items of the standard picture and cognate control stimulus set. Furthermore, to be as close to the digits as possible we controlled the four stimulus sets on frequency (Baayen, Piepenbrock & Gulikers, 1995), the amount of syllables and physical size (300x300 pixels).

The relevant language in each trial was indicated by a cue. The language cues consisted of colored squares (size 160x106 pixels) presented in green or blue at the center of the screen.

The trials were presented and the responses recorded using E-prime version 1.1.4.1. The speech onset of the vocal responses was recorded with a voice-key, while the errors were marked by the experimenter in a subject file.

Procedure

The cued language switching experiment lasted approximately 30 minutes and started with a brief explanation of the task, during which speed and accuracy were emphasized. In front of the participants was a card indicating the color-cue to language assignment, which was held constant throughout the experiment and counterbalanced across participants. Each cue was presented for 1000 ms and was preceded by a fixation point (+) for 400 ms. After the cue, the picture or digit was presented and would not disappear before a response was registered.

To get the participants acquainted with the task and voice-key, they proceeded with a practice block that consisted of 16 trials. After the practice trials, they had a chance to ask questions, which was followed by the experimental conditions.

There were four experimental blocks of 108 trials each, one for each stimulus set condition. In each block, each of the nine items was presented twelve times (six times for each language). There were an equal number of language switches and repetitions in each block. The order of the four stimulus set conditions was counterbalanced across participants.

Design

The within-subjects independent variables in the basic contrast were stimulus set (digit vs. standard picture stimulus set), language (German vs. English), and language transition (switch vs. repetition). In further preplanned contrasts, performance in digit naming was compared to that in two picture-naming control conditions: Cognate control (digit vs. cognate control stimulus set) and semantic control (digit vs. semantic control stimulus set). The dependent variables were reaction time (RT) and errors.

Results

The first trial of each block (0.9% of the data) and the error trials (7.4% of the data) were excluded from RT analyses. Furthermore, RTs in all trials were z-transformed for each stimulus set, and trials with a z-score of -4/+4 were discarded as outliers (1.3% of the data).

--- please insert Table 1 about here ---

Standard picture stimulus set vs. digit stimulus set

In this basic contrast, performance between standard pictures and digits was compared. The RT data showed significantly faster naming responses with the digit stimulus set than with the standard picture stimulus set ($F(1, 23) = 202.12$; $p < .001$; $\eta p^2 = .898$; see Table 1), and switch trials were significantly slower than repetition trials ($F(1, 23) = 36.56$; $p < .001$; $\eta p^2 = .614$). Importantly, the interaction between stimulus set and language transition was significant ($F(1, 23) = 5.06$; $p < .05$; $\eta p^2 = .180$). This interaction shows that switch costs were smaller during digit naming (43 ms) than during picture naming (72 ms; see Figure 1).

There was no significant main effect of language ($F(1, 23) = 3.29$; ns.; $\eta p^2 = .125$), even though RT was somewhat shorter for L1 (German) than for L2 (English; 703 ms vs. 716 ms). Likewise, the interactions between language and stimulus set ($F < 1$), language and language transition ($F < 1$), and the three-way interaction ($F(1, 23) = 1.04$; ns.; $\eta p^2 = .043$) were not significant.

The error data showed no significant main effect of stimulus set ($F < 1$). Switch trials were significantly more erroneous than repetition trials ($F(1, 23) = 30.77$; $p < .001$; $\eta p^2 = .572$), and there were more errors in German trials than in English trials ($F(1, 23) = 4.54$; $p < .05$; $\eta p^2 = .165$). (The higher error rate in German than in English indicates a speed-accuracy trade off with respect to language, as subjects were both faster and more erroneous in German than in English.) All two-way interactions were not significant (Fs < 1), just like the three-way interaction ($F(1, 23) = 2.00$; ns.; $\eta p^2 = .080$).

Cognate control stimulus set vs. digit stimulus set

Using the same ANOVA as in the previous analyses we examined the effect of within-item between-language phonological overlap by investigating the performance difference between the digit and the cognate control stimulus set[1]. The RT data showed significantly faster naming responses in the digit stimulus set than in the cognate control stimulus set ($F(1, 23) = 116.45$; $p < .001$; $\eta p^2 = .898$; see Table 1) and switch trials were significantly slower than repetition trials ($F(1, 23) = 43.67$; $p < .001$; $\eta p^2 = .655$). Furthermore, German trials were faster than English trials ($F(1, 23) = 5.77$; $p < .05$; $\eta p^2 = .200$). However, it is most important with respect to the focus of this study that the interaction between stimulus set and language transition was clearly not significant ($F < 1$; see Figure 1), as were all other interactions (all Fs < 1).

The error data showed no significant main effect of stimulus set ($F < 1$). Switch trials were significantly more erroneous than repetition trials ($F(1, 23) = 29.33$; $p < .001$; $\eta p^2 = .560$) and there were more errors in German trials than in English trials ($F(1, 23) = 4.24$; $p < .05$; $\eta p^2 = .156$), again indicating a speed-accuracy trade-off. The interaction between stimulus set and language transition was not significant ($F(1, 23) = 2.79$; ns.; $\eta p^2 = .108$), like the other interactions (Fs < 1).

Semantic control stimulus set vs. digit stimulus set

Using the same ANOVA as in the previous analyses, we examined the effect of semantic relations between items by investigating the performance difference between digits and semantically-related items[2]. The RT data showed significantly faster naming responses with the digit stimulus set than with the semantic control stimulus set ($F(1, 23) = 235.73$; $p < .001$; $\eta p^2 = .911$; see Table 1), and switch trials were significantly slower than repetition trials ($F(1, 23) = 21.91$; $p < .001$; $\eta p^2 = .488$). Naming in German was significantly faster than in English ($F(1, 23) = 7.70$; $p < .05$; $\eta p^2 = .251$).

Crucially, the interaction between stimulus set and language transition was significant ($F(1, 23) = 4.59$; $p < .05$; $\eta p^2 = .166$), with smaller switch costs during digit naming (43 ms) than picture naming (81 ms; see Figure 1). This interaction thus replicates the effect found in the comparison of the digit stimulus set and the standard picture stimulus set. This suggests that semantic relations between items (which are present both in the digit set and the semantic control set) are not the main cause for performance differences between digits and pictures.

The interactions between language and stimulus set ($F(1, 23) = 3.99$; ns.; $\eta p^2 = .148$) and language and language transition ($F < 1$) were not significant. The three-way interaction was not significant as well ($F < 1$).

The error data showed no significant main effect of stimulus set ($F(1, 23) = 2.78$; ns.; $\eta p^2 = .108$). Switch trials were significantly more erroneous than repetition trials ($F(1, 23) = 26.82$; $p < .001$; $\eta p^2 = .538$), and there were more errors for German than for English ($F(1, 23) = 5.88$; $p < .05$; $\eta p^2 = .204$), again indicating a speed-accuracy trade-off. All interactions were not significant (Fs < 1).

--- please insert Figure 1 about here ---

Discussion

In this study we investigated the effect of stimulus type (digits/pictures) on switching between languages (German-English) in order to establish the comparability of effects. To match the characteristics of digits, we added two picture control sets: a cognate control stimulus set, which constituted of pictures depicting cognates, and a semantic control stimulus set, which consisted of semantically-related pictures. The voice-onset data showed that digit naming was overall faster than all three picture stimulus sets. Furthermore, switch costs were smaller for digit naming when comparing the digit stimulus set and the standard picture stimulus set and the digit stimulus set and the semantic control stimulus set. However, there was no switch cost difference between the digit stimulus set and the cognate control stimulus set. Finally, none of the analyses in the current study showed asymmetrical switch costs.

In the following, we first discuss the influence of stimulus type on language switch costs using naming tasks. Then we discuss the issue of asymmetrical switch costs.

Influence of stimulus type on language switch costs

Importantly, with respect to the focus of the present study, the results showed smaller switch costs in digit naming than in picture naming (i.e., the digit effect), which is a novel finding in language switching. This finding should encourage researchers to be cautious when comparing across language switching studies that utilize different stimulus types, as these could have a significant effect on the outcome.

As we kept the number of stimuli constant in each condition, the observed digit effect does not include differential stimulus-based priming (e.g., Koch & Allport, 2006) that characterizes language switching studies that implement either small/repeated stimulus sets vs. large/unique stimulus sets. Furthermore, we are confident that the digit effect was not caused by differential preparation effects in digit vs. picture naming. Prior studies using pictures have found that preparation leads to smaller switch costs (Costa & Santesteban, 2004; Verhoef, Roelofs & Chwilla, 2009), while preparing to name digits leads to larger switch costs (Philipp, Gade & Koch, 2007). However, this difference with respect to preparation can certainly not explain the smaller switch costs in digit naming than in picture naming in the present study where there is a long preparation time.

To account for the origin of this switch cost difference between digit and picture stimuli, it is important to focus on different targets of language control in the bilingual language production process. Prior to articulation in the intended language, concepts go from the activation of semantic concepts via lexical selection to phonological processing (see, e.g., Indefrey & Levelt, 2004; Levelt, Roelofs, & Meyer, 1999).

As regards semantic information and lexical selection, one could argue that picture naming resulted in larger switch costs than digit naming because the latter forms a specific semantic group. However, the difference in switch costs obtained between the standard picture stimulus set and the digit stimulus set was also found between the semantic control stimulus set and the digit stimulus set. This suggests that the switch cost difference obtained between the standard picture stimulus set and the digit stimulus set is not caused by the digits' semantic group characteristic.

In order to further examine the role of semantics during bilingual digit naming, we re-analyzed the digit data. This re-analysis was focused on a specific marker for semantic influence on language control, namely the numerical distance effect. This is a facilitation effect that occurs when two consecutive numbers have a small numerical distance (e.g., Brysbaert, 1995). With respect to the present study, the numerical distance effect might play a role for the difference between digit and picture naming, since this effect only influences digit naming but not picture naming.

To test the influence of this effect on language switch costs we re-analyzed the digit data using a 2(switch vs. repetition) x 2(small vs. large numerical distance) analysis, with small numerical distance consisting of a numerical difference of three or smaller between two consecutive trials (Herrera & Macizo, 2011). The results showed that a small numerical distance causes larger switch costs than when the numerical distance is large (71 ms vs. 23 ms; $\underline{F}(1, 23) = 14.39$; $\underline{p} < .001$; $\eta p^2 = .385$). The numerical distance effect in bilingual digit naming provides evidence that priming of numerical semantic information influences language control. However, since a small numerical distance actually enhances switch costs, it can be concluded that this effect did not cause the smaller switch costs in digit than in picture naming. This effect also implies that if numerical distance had been kept to a maximum throughout the experiment, an even larger switch cost difference would have been found between digit and picture naming.

The influence of numerical distance on switch costs provides evidence that digit naming is influenced by semantic information in language switching. This is not in line with the asemantic route during digit naming that is postulated in several models (e.g., McCloskey, 1992) and supported by several studies (e.g., Herrera & Macizo 2010, 2011; Roelofs, 2006). Similarly, during picture naming, we know that semantic information is activated as well (e.g., Glaser & Düngelhoff, 1984; Smith & Magee, 1980). So, it seems unlikely that a difference in route, with respect to semantic activation, would have lead to the difference that was observed in our data.

In fact, yet another characteristic of digits that served as a possible target for the difference between bilingual digit naming and bilingual picture naming referred to cognate status. One of the characteristics of cognates is that they have a large overlap in phonology between languages. In the present study no switch cost difference was found between the digit stimulus set and the cognate control stimulus set, whereas we did find such a difference between the digit stimulus set and the other two picture sets. This data pattern provides evidence that the main difference between bilingual digit naming and picture naming is based on the cognate status of digits and thus most likely on the phonological level. It is interesting to note that in the task switching domain several studies have provided evidence for the influence of similarly “late” response-related processes, like response execution, on switch costs (e.g., Koch & Philipp, 2005; Philipp, Jolicoeur, Falkenstein, & Koch, 2007; Schuch & Koch, 2003; for a review see Kiesel, et al., 2010), so that it appears likely that processes associated with vocal response execution or articulation influence switch costs. Both the results of the current study and previous task switching studies leads us to believe that phonology might play a considerable role during language switching.

At the moment we can only speculate about the nature of this difference. One possibility is that the phonological co-activation of both languages, caused by the cognate status (e.g., Costa et al., 2000; Hoshino & Kroll, 2008), might have played a role. This phonological co-activation would result in a higher activation of the non-target language when using cognates than when using non-cognates, which in turn would result in reduced performance costs in language switch trials, while in the repetition trials the dual phonological activation would cause a larger amount of interference. Taken together, phonological co-activation of both languages would decrease switch costs, which is in line with the present data.

Our results indicate that language switching studies using digits that implemented languages of the same language family could be regarded as cognate language switching studies. The finding that performance differences between digit naming and picture naming during language switching are primarily due to the cognate status of many digits can be regarded as evidence for this. However, some caution is needed since Verhoef, Roelofs and Chwilla (2009) found no difference in switch costs between pictures depicting cognate and non-cognates and Christoffels, Firk and Schiller (2007) even found that pictures depicting cognates elicit larger switch costs than non-cognates. Thus, digit naming language switching studies should be regarded as distinctive cognate language switching studies, since additional processes, like the numerical distance effect, might come into play when naming cognate digits and not cognate pictures.

We demonstrated that both stimulus types (i.e., digits and pictures) have a divergent influence on switch costs. While this effect renders it difficult to directly compare studies that use different stimulus types, it should also encourage researchers to think about what stimulus type to use in future language switching studies. Whereas digits represent a separate semantic group and are influenced by the numerical distance to the previous trial, they do allow for very comparable results over studies, since generally the same nine stimuli are used in each study. This is not the case during picture naming studies, which do not only use different concepts, but utilize different picture sets. Pictures do allow for more diverse research, because they represent a much larger and varied set of stimuli. This also entails that these stimuli would allow for larger ecological validity. However, this variety can also be problematic. For one, the name agreement of pictures is not as optimized as for digits. Along the same lines, the name in one language might refer to one or more concepts in another language, whereas this is not the case when using digits. Additionally, it is harder to control a picture set, for example for semantic or phonological influences.

This switch cost difference between stimulus types should also encourage language switching research with stimuli other than digits and pictures depicting concrete objects, since it is likely (and demonstrated in the present study) that different stimuli generate differences in language switch costs. This study should stimulate research of other word categories in language switching, for example verbs with action pictures, or the difference between word categories, for example verbs and nouns, with respect to language switching.

Switch cost asymmetry in language switching using naming tasks

It is important to note that we found symmetrical switch costs during bilingual digit naming. Previous studies using digit naming consistently found asymmetrical switch costs, with L1 showing larger switch costs than L2 (e.g., Meuter & Allport, 1999; Philipp et al., 2007). While we also found symmetrical switch costs for the picture stimulus sets[3], there is a curious difference between the data of these three picture stimulus sets and the digit stimulus set. We found no significant difference in asymmetry between the picture stimulus sets and the digit stimulus set, whereas it appears that for the digit set the switch costs are numerically larger for L1 than L2 (47 ms vs. 38 ms), this is numerically reversed for the picture sets with larger switch costs for L2 than L1 (standard picture: 64 ms vs. 79 ms; cognate control: 46 ms vs. 56 ms; semantic control: 79 ms vs. 81 ms). This numerical difference in pattern between picture naming and digit naming during language switching might tempt one to speculate that the type of stimulus has an influence on the (a)symmetry of switch costs across languages.

The fact that we found symmetrical switch costs for all the analyses led us to take a closer look at the influence of preparation time and “decay” on the switch cost asymmetry. There are two partially overlapping markers when using a switching task to investigate decay. The first being the response-to-stimulus interval (RSI), which lets us investigate passive decay, and the response-to-cue interval (RCI), which lets us investigate decay without the influence of active preparation (for a review on decay in task switching see, Kiesel et al, 2010).

That RSI would influence the asymmetry across languages comes from the comparison between two studies, i.e. Verhoef, Roelofs and Chwilla (2009) and Philipp, Gade and Koch (2007). Verhoef, Roelofs and Chwilla (2009) found that switch costs were asymmetric with a short CSI (500 ms), whereas with a long CSI (1250 ms) they found symmetric switch costs. It needs to be taken into account that in Verhoef, Roelofs and Chwilla's (2009) study the RSI was not kept equal between the long and short CSI condition. In the short CSI condition RSI was 750 ms long, whereas in the long CSI condition the RSI was 1500 ms. In contrast, Philipp, Gade and Koch (2007) did not find any switch cost difference across languages using a short CSI (100 ms) and a long CSI (1000 ms) while keeping the RSI equal (1100 ms). This could indicate that switch cost asymmetry is perhaps not so much influenced by the preparation time between cue and stimulus, but more by the amount of time passed from the last response (RSI), providing evidence that switch cost asymmetry is also susceptible to passive decay. Consequently, the symmetrical switch costs found in the present study could be due to the large RSI, which was 1400 ms in the current study. However, since Philipp, Gade and Koch (2007) implemented digits and Verhoef, Roelofs and Chwilla (2009) implemented pictures there might be additional processes at work, which render it difficult to compare the results of these two studies.

Furthermore, Verhoef, Roelofs and Chwilla (2009) assumed that the switch cost asymmetry across languages is due to a larger L1-repetition benefit than L2-repetition benefit. This hypothesis comes from the assumption that there is no interference of L2 during L1 repetition trials, while there is interference of L1 on L2 repetition trials. In a task switching study, Horoufchin, Phillip and Koch (2011) found that RCI has a large impact on the task-repetition benefit. Thus, we assume that RCI also plays a crucial role for the language switch cost asymmetry. Further research is needed to confirm this hypothesis and to examine the role of RSI and RCI on language switching.

Conclusion

The present study revealed smaller language switch costs in digit naming than in picture naming, suggesting that bilingual digit naming requires less language control than picture naming. However, this difference was abolished when the pictures represented cognates, suggesting that within-item phonological priming reduces language switch costs and can explain differences between bilingual digit naming and picture naming in most conditions.

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Footnotes

[1] A paired t-test showed that the pictures depicting cognates were named faster than the standard pictures ($t(23) = 4.64$; $p < .001$), indicating that the manipulation of the cognate control stimulus set was successful.

[2] A paired t-test showed that standard pictures were named faster than the semantically-related pictures ($t(23) = 2.15$; $p < .05$), indicating that the manipulation of the semantic control stimulus set was successful, even though different pictures were used in both stimulus sets, and the semantic control stimulus set consisted of pictures depicting objects referring to only one single semantic group. Generally, the same pictures are used during semantic blocking studies and more than one semantic group is implemented.

[3] A 2(German vs. English) x 2(switch vs. repetition) ANOVA of the digit data showed that the interaction between language and language sequence was not significant ($F(1, 23) = 0.82$; ns.; $\eta p^2 = .034$). As was the data for the standard picture stimulus set ($F(1, 23) = 0.52$; ns.; $\eta p^2 = .018$), cognate control stimulus set ($F(1, 23) = 0.19$; ns.; $\eta p^2 = .008$) and semantic control stimulus set ($F(1, 23) = 0.92$; ns.; $\eta p^2 = .000$).

Table 1. RT in ms (and error percentage) as a function of language transition (repetition vs. switch), Language (L1 vs. L2) and stimulus sets (digit, standard picture, cognate control, and semantic control stimulus set).

	L1		L2	
	Switch	Repetition	Switch	Repetition
Digit	581 (1.7)	534 (0.4)	589 (1.4)	551 (0.3)
Standard picture	881 (1.6)	817 (0.8)	901 (1.5)	822 (0.3)
Cognate control	796 (1.5)	750 (0.8)	815 (1.1)	759 (0.5)
Semantic control	916 (1.9)	837 (0.9)	960 (1.5)	879 (0.5)

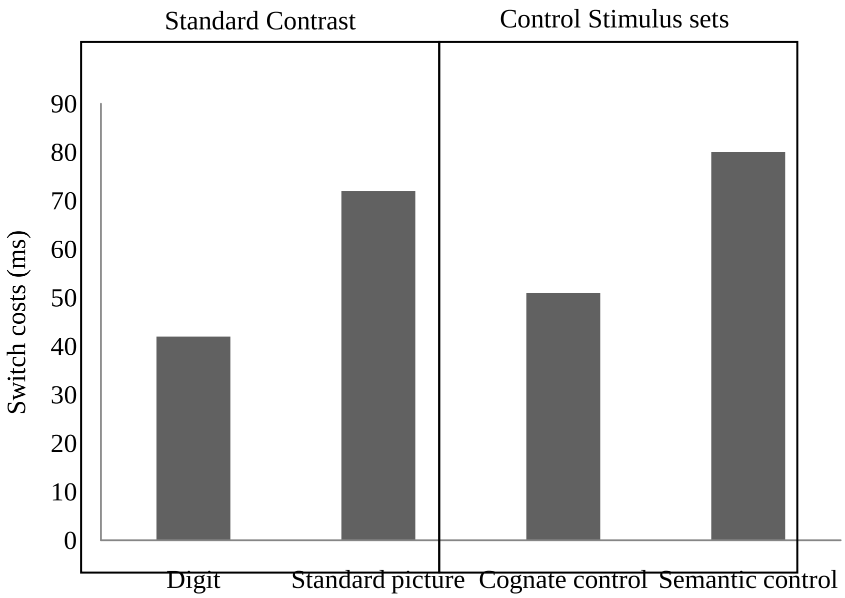

Figure 1. Switch costs in ms as a function of stimulus set (digit, standard picture, cognate control and semantic control stimulus set).

Appendix.

	English	English IPA	German	German IPA
Digit stimulus set	one	wʌn	Eins	aɪ̯ns
	two	tu	Zwei	t͡svaɪ̯
	three	θɹi	Drei	dʀaɪ̯
	four	fɔːɹ	Vier	fiːɐ̯
	five	faɪv	Fünf	fʏnf
	six	sɪks	Sechs	zɛks
	seven	ˈsɛv.ən	Sieben	ˈziːbm̩
	eight	eɪt	Acht	aχt
	nine	naɪn	Neun	nɔɪ̯n
Standard picture stimulus set	city	ˈsɪti	Stadt	ʃtat
	clock	klɑk	Uhr	uːɐ̯
	doctor	ˈdɑk.tɚ	Arzt	aːɐ̯t͡st
	tree	tɹiː	Baum	baʊ̯m
	boy	bɔɪ	Junge	ˈjʊŋə
	car	ˈkɑː	Auto	'aʊ̯to
	horse	hɔː(r)s	Pferd	pfeːɐ̯t
	star	stɑɹ	Stern	ʃtɛʁn
	table	ˈteɪbəl	Tisch	tɪʃ
Cognate control stimulus set	foot	fʊt	Fuß	ˈfuːs
	man	mæn	Mann	man
	sun	sʌn	Sonne	ˈzɔnə
	fish	ˈfɪʃ	Fisch	fɪʃ

	house	haʊs	Haus	haʊ̯s
	ball	bɔl	Ball	bal
	fire	faɪɚ	Feuer	ˈfɔɪ̯ɐ
	boat	boʊt	Boot	boːt
	book	bʊk	Buch	buːχ
Semantic control stimulus set	ear	iɚ	Ohr	oːɐ̯
	woman	ˈwʊmən	Frau	fʁaʊ̯
	head	hɛd	Kopf	kɔpf
	neck	nɛk	Hals	hals
	tooth	tuːθ	Zahn	ʦaːn
	leg	lɛg	Bein	baɪ̯n
	girl	gɝl	Mädchen	ˈmɛːtçən
	eye	aɪ	Auge	ˈaʊ̯gə
	nose	noʊz	Nase	ˈnaːzə