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Two languages, two minds: Flexible cognitive processing driven by language of operation.

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Two languages, two minds: Flexible cognitive processing driven by language of operation

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Author contributions

P. Athanasopoulos, E. Bylund and N. Riches designed the research; P. Athanasopoulos, L. Damjanovic, A. Schartner, and A. Kibbe performed the research; P. Athanasopoulos and E. Bylund prepared the data for analysis, and G. Montero-Melis and N. Riches analyzed the data; L. Damjanovic and G. Thierry prepared the graphs; and P. Athanasopoulos, G. Thierry, E. Bylund, G. Montero-Melis wrote the paper, with feedback from the rest of the co-authors.

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Abstract

We make sense of objects and events around us by classifying them into identifiable categories. The extent to which language affects this process has been the focus of a long-standing debate: Do different languages cause their speakers to behave differently? Here, we show that fluent German-English bilinguals categorize motion events according to the grammatical constraints of the language in which they operate. First, as predicted from cross-linguistic differences in motion encoding, participants functioning in a German testing context prefer to match events on the basis of motion completion to a greater extent than participants in an English context. Second, when participants suffer verbal interference in English, their categorization behavior is congruent with that predicted for German and when we switch the language of interference to German, their categorization becomes congruent with that predicted for English. These findings show that language effects on cognition are context-bound and transient, revealing unprecedented levels of malleability in human cognition.

Main text

Charlemagne, King of the Franks and self-proclaimed Emperor of the Romans, observed that to speak another language is to possess another soul. Can something as fundamental as categorization preferences in humans (Harnad, 2005) be shifted by changing the language context in which such categorization is performed? Language may provide a ready basis of information for the purposes of habitually classifying the world into meaningful categories (Lucy, 1997; Whorf, 1956). For instance, faces, colors, events, and artificial stimuli are learned faster and discriminated better if they have specific linguistic labels attached to them (e.g., Kikutani, Roberson & Hanley, 2008; Lupyan & Ward, 2013). Infants exposed to different languages show differences in color categorization as soon as they are able to name colors in their native language (Roberson, Davidoff, Davies & Shapiro, 2004). Such effects have been shown to extend to low-level perception (Thierry, Athanasopoulos, Wiggett, Dering & Kuipers, 2009). Here, we explore the possibility that using a specific language causes differences in ongoing cognitive processing, by manipulating the language of operation in bilingual individuals and measuring their performance in a categorization task.

In two experiments, we asked German-English bilinguals to provide similarity judgments on video-clip triads depicting goal-oriented motion events (e.g., a woman walking towards a car). Previous research shows that speakers of different languages attend differently to the goal, or endpoint, of a motion event. Speakers of German, Afrikaans, and Swedish, tend to mention endpoints, look at endpoints, and favor endpoints in similarity judgments, whereas speakers of English, Spanish, Arabic, and Russian, do so to a lesser extent (Athanasopoulos & Bylund, 2013; Bylund, Athanasopoulos & Oostendorp, 2013; Flecken, Carroll & von Stutterheim, 2014; von Stutterheim, Andermann, Carroll, Flecken & Schmiedtová, 2012). These crosslinguistic differences in endpoint preference arise because of the category of viewpoint aspect, a grammatical device that locates events in time: In English, Russian, Arabic, and Spanish, the ongoing phase of an event is obligatorily marked on the verb (e.g., the progressive *–ing* form in English), and speakers of these languages are therefore more prone to view events as ongoing, defocusing the endpoint. In contrast, German, Afrikaans, and Swedish lack viewpoint aspect, and speakers of these languages are therefore not pointed by their grammars to ongoingness. Instead, they adopt holistic event perspectives whereby endpoints are included (see further Bylund et al., 2013; von Stutterheim et al., 2012).

In the first experiment we elicited event categorization patterns of German and English monolinguals and German-English bilinguals in an all-English and an all-German context. If different languages are linked to differences in event categorization then performance in this task will vary according to language context. In the second experiment we disrupted verbally mediated categorization by asking a different group of bilinguals to repeat strings of numbers in their first and second language. Crosslinguistic differences between monolinguals disappear in the presence of verbal interference. However, when bilinguals use one of their languages, the other language remains active and fully accessible, affecting all other representations to which it is connected (Abutalebi & Green, 2007; Boutonnet, Athanasopoulos & Thierry, 2012; Wu & Thierry, 2010). We reasoned that varying the language in which verbal interference occurs in bilinguals would selectively free up the unaffected language as a source of information for similarity judgments. Verbal interference in language A should make the task of holding on to an event representation in that language difficult, but encoding the event in language B (the non-interfered language) should still be possible and influence categorization behavior. Crucially, we also explored the extent to which bilinguals can flexibly switch to the other categorization pattern by changing the language of interference halfway through the task, thus providing a within-subjects manipulation to control for the possible presence of extra-linguistic cultural differences between the populations of interest (Casasanto, 2005; Levinson, 2000).

Experiment 1: Does language context shift categorization preferences?

Method

Participants. Sixty adults with an age-range of 20-28 years old, and with similar socioeconomic and education backgrounds (all University students coming from middle class suburban backgrounds) took part in the study. Fifteen were monolingual English speakers tested in the UK, and fifteen were monolingual German speakers tested in Germany. Given that it is virtually impossible to find completely monolingual German native speakers who are also educated to University level, we made sure that these participants were not using English as part of their degree, or in their daily activities. All of them self-rated their proficiency in English as poor or basic, which was confirmed by their scores on the Quick Oxford Placement Test (QPT, 2001), an English proficiency test (*M* = 42.13%, *SD* = 6.38, indicating Elementary level). Thirty German-

English bilinguals (with German as the first/native language and English as the second language) were randomly allocated to one of two groups of fifteen participants each. One group interacted with the experimenter entirely in German, received task instructions in German, and completed the consent form and biographical questionnaire in German. The other group of bilinguals interacted with the experimenter entirely in English, received task instructions in English, and completed the consent form and biographical questionnaire in English. Both groups had comparable English proficiency, above Elementary level as assessed through the QPT ($M = 74\%$, $SD = 11.26$ for the bilinguals tested in a German-speaking context; $M = 72\%$, $SD = 9.03$ for the bilinguals tested in an English-speaking context; $t(28) = .50$, $p = .62$), and comparable ages of L2 acquisition ($M = 11$ years old, $SD = 1.31$ for the bilinguals tested in a German-speaking context; $M = 11$ years old, $SD = 1.06$ for the bilinguals tested in an English-speaking context, $t(28) = .92$, $p = .37$). Fifteen participants per group was deemed satisfactory in terms of statistical power based on our own previous studies using similar sample sizes in the same task (Athanasopoulos & Bylund, 2013; Bylund et al., 2013) and previous motion categorization studies (e.g., Gennari, Sloman, Malt & Fitch, 2002).

Materials and Procedures. Similarity judgement data were elicited using the sequential triads matching task used previously in Athanasopoulos and Bylund (2013), using clips from the stimulus pool of the research group of von Stutterheim and associates (e.g., von Stutterheim et al., 2012). The stimuli consisted of 19 triads of video clips, consisting of a target clip and two alternate clips. The target clip showed motion towards a specific goal (for example a person walking towards a car) but the arrival at it was not overtly shown (intermediate degree of goal-orientation). The alternates showed either motion with arrival at a goal (for example a person walking into a building), indicating motion completion and therefore a high degree of goal-orientation, or motion with a possible goal far away from the agent (for example a person walking along a road, with a building/forest/village in the distance), highlighting ongoingness and therefore a low degree of goal-orientation (see Fig. 1). Triads were created (and clips edited where necessary) in such a way as to control for manner and direction of motion and number and gender of agents. All clips were 6 seconds long.

The experiment was administered using Microsoft Powerpoint. Participants were informed that they would see video clips arranged in triads on the computer screen, with clip A appearing first, then clip B, and finally clip X (the target). Participants were instructed to indicate to the experimenter orally whether they thought clip X was more similar to clip A or more similar to clip B. In a counter-balanced design half of the time the ongoingness alternate appeared first (clip A) and half of the time it appeared second (clip B), and vice versa for the motion completion alternate. A total of thirty-eight triads were thus presented in a completely random order. The precise sequence of the clips in each triad was as follows: Clip A played, followed by clip B, followed by clip X. Participants were instructed to give their responses only after they had watched clip X in its entirety. Clips played immediately after one another, with no pause in-between. Inter-trial interval was self-paced until the participant had given their answer to the experimenter, at which point the experimenter initiated the next trial. Bilingual speakers used English to report their judgements in the English-testing context and German to report their judgments in the German testing context.

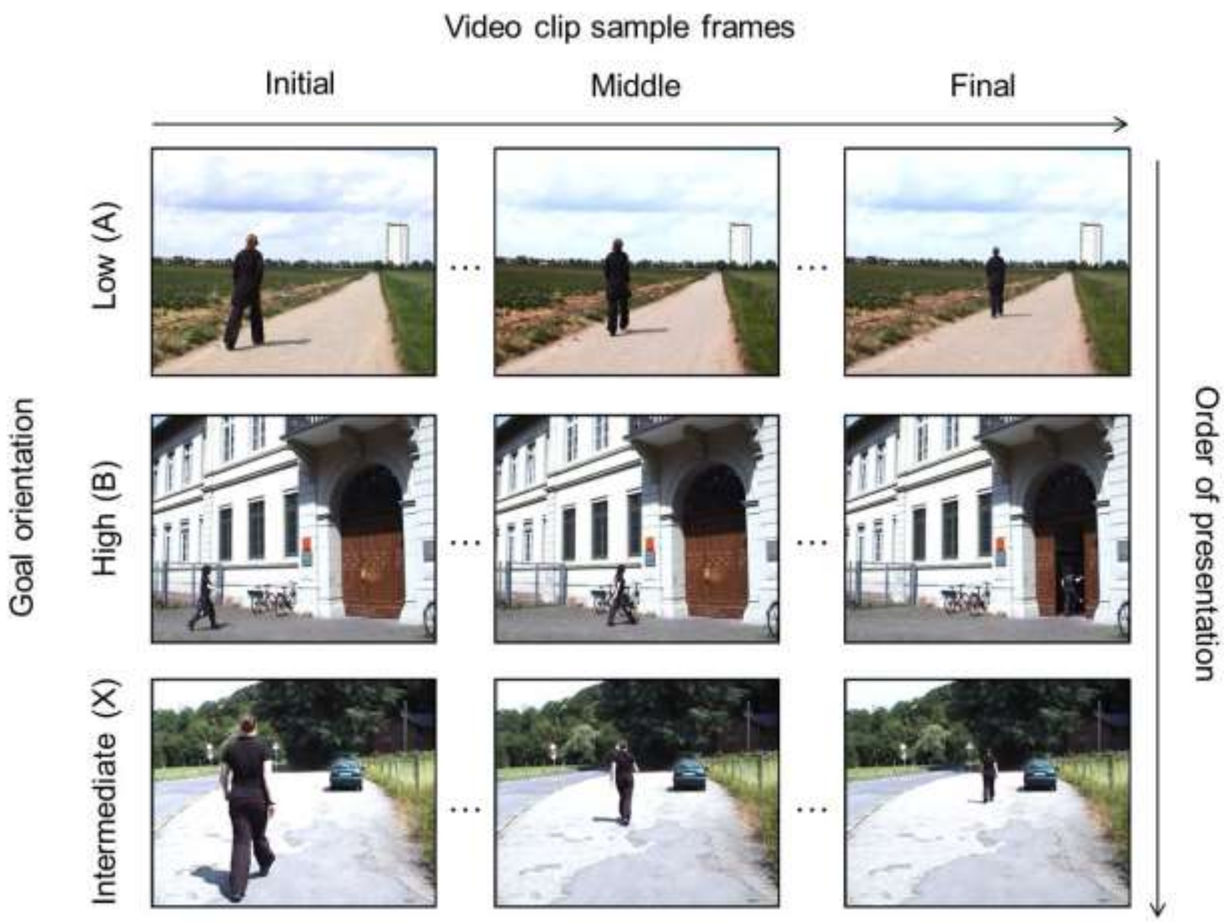

Figure 1. Example of a triad of clips with high, intermediate, and low degree of goal orientation, representing the initial, middle, and final point of the clip. Each clip was 6 seconds long. Clips in each triad appeared automatically after one another. Each triad was initiated by the experimenter.

The videos have been normed for visual similarity in a previous study with English and Swedish speakers (Athanasopoulos & Bylund, 2013), ensuring that language groups do not differ in how they perceive the visual similarity between each of the alternates and the corresponding target. In this study, we also asked ten German native speakers to provide visual similarity ratings to ensure that those were comparable to the ones obtained previously from English speakers. This was done by using a still of the initial frame from each video (because we wanted to avoid the factor of the motion event, which was the crucial experimental variable), and arranging a presentation whereby a still of each alternate video was presented alongside a still of the corresponding target video. Thus two types of pairs of pictures were created, one type that contained a motion completion alternate and its corresponding target, and one type that contained an ongoingness alternate and the relevant target. Each pair appeared twice, with the left/right position counterbalanced. Ten German native speakers who did not take part in any of the main experiments were asked to rate the members of each pair of pictures for visual similarity on a 9 point Likert scale where 1 represented 'very dissimilar' and 9 represented 'very similar'. For the English speakers in our previous study (Athanasopoulos & Bylund, 2013) the mean similarity rating of the motion completion alternates and their corresponding target was 4.29 (SD = 1.13), while the mean similarity rating of the ongoingness alternates and their relevant targets was 4.49 (SD = 1.19). For the German speakers in this study the mean similarity rating of the motion completion alternates and their corresponding target was 4.33 (SD = 0.78), while the mean similarity rating of the ongoingness alternates and their relevant targets was 4.91 (SD = 0.99). A 2 (Group: German vs. English) x 2 (Pair type: motion completion alternate and target vs. ongoingness alternate and target) mixed ANOVA showed no significant interaction, $F(1, 21) = 2.02$, $p = 0.170$. This means that the two language groups did not differ in how they perceived the relative visual similarity between each alternate and its corresponding target.

We also took the additional measure of establishing the degree to which English and German monolinguals mention event endpoints in their verbal description of the stimuli with intermediate degree of goal orientation. This step is necessary as the predictions for the non-verbal tasks rest on the assumption that German speakers are more prone to mention the goal of events than English speakers do. To this end, 15 German monolinguals who did not take part in any of the other experiments were asked to provide verbal descriptions of 12 video clips showing motion towards a specific goal without showing whether the goal was reached or not (intermediate degree of goal-orientation). Six filler clips that showed an action not including goal oriented motion (e.g., a woman drinking coffee) were also included. All 18 clips were shown in a fully randomized order for each participant. English monolingual data were obtained from a random subset of 15 participants who took exactly the same task, reported in our previous study (Athanasopoulos & Bylund, 2013). Results showed that on average, English monolinguals included goal information 37% of the time, while German monolinguals included it 62% of the time. To verify the statistical significance of this pattern we fitted a mixed logit regression model to the data, modelling the binary dependent variable Goal Encoding as a function of Group (2 levels: English Monolinguals, German Monolinguals) as fixed effects, and with random intercepts for subjects and items. The model showed that the difference between English and German monolinguals was highly significant ($\beta_1 = 1.21$, SE = 0.24, Wald $z = 5.00$, $p < 0.001$).

Results

Analyses were run in R (R Development Core Team, 2013) using the lme4 library (Bates, Maechler, Bolker, & Walker, 2014). Since the proportion of motion completion preferences (high degree of goal orientation) is 1 minus the proportion of ongoingness preferences (low degree of goal orientation), we used the former as the dependent variable throughout the statistical analyses. We used logit mixed models to predict the likelihood in log-odds space that a speaker would choose a completion alternate. The analysis modelled the binary dependent variable Completion Choice (yes, no) using Group (four levels: German Monolinguals, Bilinguals in German Context, Bilinguals in English Context, English Monolinguals) as a first-level fixed factor. Additionally, we included the Order in which the item appeared (two levels: completion alternate first or second) as a fixed-effects nuisance factor so as to control for any effects it could have on completion choices. Including a by-subject random slope for Order led to an overparameterized model (correlation of –1.00 of the intercept and slope for the subject random effects), so we simplified the final model to include crossed random intercepts for subjects and items. Collinearity was not an issue in this model (all fixed effect correlations $|r| < 0.5$; for all predictors VIF < 1.93).

Including Group in the model significantly increased the fit compared to a null model including Order only ($\chi^2(3) = 39.2$, $p < .001$), thus indicating a main effect of Group. We used forward difference coding for the Group factor to directly address our hypothesis that speakers in a German language context would be more likely to choose completion alternates than speakers in an English language context. The intercept represents the grand mean of the likelihood of choosing a completion alternate, while each coefficient compares the mean of one level to that of the next level. The negative intercept (β_0 = - 0.99, *SE* = 0.30, Wald *z* = - 3.35, $p < 0.001$) indicates that participants showed an overall preference for ongoingness alternates. However, as Figure 2 shows, the degree of this preference varied as a function of language testing context. Bilinguals in a German context selected significantly more motion completion alternates than bilinguals in an English context (β_2 = 0.712, *SE* = 0.18, Wald *z* = 3.92, $p < 0.001$) and did not differ significantly from German monolinguals (β_1 = 0.13, *SE* = 0.18, Wald *z* = 0.75, p = 0.45). Bilinguals in an English context did not differ significantly from English monolinguals (β_3 = 0.31, *SE* = 0.19, Wald *z* = 1.65, *p* = 0.10). The comparison between both monolingual groups is implicit given forward difference coding: each of the groups was compared to the following one as to their likelihood of choosing a completion alternate. This resulted in the following ordering: German monolinguals > bilinguals in German context > bilinguals in English context > English monolinguals, where > indicates "significantly greater than". As expected, German monolinguals selected more motion completion alternates than English monolinguals (Fig. 2), a pattern that conforms to the differences between monolinguals in their verbal behaviour (see materials section).

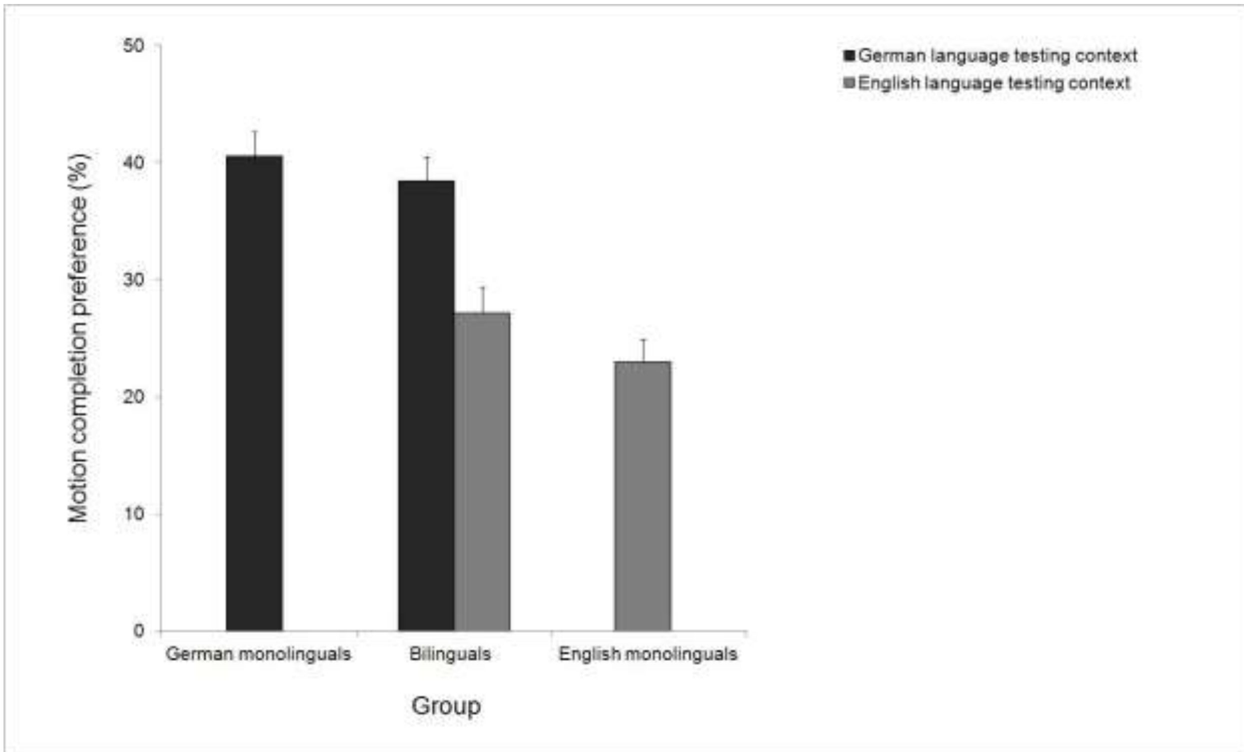

Figure 2. Motion completion preferences (%) in Experiment 1 (varying language context). Columns show group means. Error bars show standard error of the mean.

Experiment 2: Does switching the language of verbal interference shift categorization preferences to the non-interfered language?

Method

Participants. Thirty German-English bilinguals (with German as the first/native language and English as the second language) aged between 21-36 years were randomly allocated to one of two groups of fifteen participants each. One group was instructed to perform the interference task in German, and then halfway through the task was asked to switch to English. This group interacted with the experimenter entirely in German, the consent form was written in German, all of the task instructions were in German, and the linguistic background questionnaire was written in German. Their mean QPT score was 80% (*SD* = 15.45), and their mean age of L2 acquisition was 10 years old (*SD* = 1.01). The other group of bilinguals was instructed to perform the interference task in English, and then halfway through the task was asked to switch to German. This group interacted with the experimenter entirely in English, the consent form was written in

English, all of the task instructions were in English, and the linguistic background questionnaire was written in English. Their mean QPT score was 83% (*SD* = 9.67), and their mean age of L2 acquisition was 10 years old (*SD* = 1.66). The two groups did not differ in their QPT scores, $t(28) = .78$, $p = .44$, or their mean age of L2 acquisition, $t(28) = 0.00$, $p = 1$.

Stimuli and procedure. Categorization patterns were elicited using the same materials and procedure as in Experiment 1, with the exception that at the onset of each triad participants heard a string of three two-digit numbers (e.g., 37, 41, 54) and were asked to repeat the string out loud and continue to repeat it until they had watched all three clips in sequence (cf. Athanasopoulos & Bylund, 2013; Trueswell & Papafragou, 2010). When the third (target) clip finished playing, participants were instructed to stop repeating the number sequence and give their response to the task administrator. One group of bilinguals was instructed to perform the interference task in German, and then halfway through the task were asked to switch to English. That is, this group was told that they would hear a string of three two-digit numbers in German and were asked to repeat the digits in German for the first 19 trials. Then, after a very short break, they were told that they would now hear a string of three two-digit numbers in English for each trial, and they were asked to repeat the digits in English. For each triad, participants heard and had to reproduce a different string of numbers that had been randomly generated for each triad and for each participant. The other group of bilinguals was instructed to perform the interference task in English, and then halfway through the task were asked to switch to German. None of the participants were told at the beginning of the task that the language in which they would hear and repeat the numbers would change halfway through the task. The language in which speakers were asked to report their preferences changed with the interference switch.

Results

As in experiment 1, we used logit mixed models to predict the likelihood in log-odds space that a speaker would choose a completion alternate. The analysis modelled the binary dependent variable Completion choice (yes, no) using Group (two levels: English—German interference, German—English interference), Phase (pre-switch, post-switch), and their interaction as fixed effect predictors. In addition, we included the Order in which the item appeared (two levels: completion alternate first or second) as a fixed-effects nuisance factor so as to control for any effects it could have on completion choices. The model's random effects structure was determined by choosing the maximal structure that converged, and removing random slopes if they were perfectly correlated among each other or with the random intercept (Baayen, Davidson & Bates, 2008). The final model included crossed random intercepts by subject and item, and by-item random slopes for Group and Phase. Collinearity was not an issue in this model (all fixed effect correlations $|r| < 0.06$; for all predictors VIF < 1.01).

All the fixed effects from the final model are reported in Table 2. The negative intercept reflects the fact that participants showed an overall preference for ongoingness, rather than completion alternates. The significantly positive coefficient for Order (a nuisance factor which we control for) indicates that participants were more likely to choose the completion alternate if it appeared second, rather than first. There was no main effect of Group, indicating that none of the two bilingual groups differed overall in their likelihood to choose completion alternates. The same was true for Phase, which did not overall predict completion choices. However, there was a significant cross-over interaction between Group and Phase, reflecting the fact that Phase (pre- or post-switch) had an opposite effect on the two groups (see Figure 3): Bilinguals who started with English interference were more likely to select motion completion alternates under English (pre-switch) than German interference (post-switch). Reciprocally, bilinguals starting under German interference were less likely to select motion completion alternates in the pre-switch phase (while exposed to German interference) than in the post-switch phase (when exposed to English interference).

Table 1
Fixed effects from final mixed logit model of likelihood to choose a completion alternate in log-odds space.

Effect	Estimate	*S.E.*	Wald *Z*
Intercept	-0.80	0.18	-4.33 ***
Order (completion second vs. first)	0.17	0.07	2.47 *
Group (German—English vs. English—German)	-0.13	0.09	-1.37
Phase (post-switch vs pre-switch)	0.03	0.07	0.49
Group × Phase	0.22	0.07	3.15 **

Interactions that do not appear in this model did not significantly improve the fit. Formula in R:
CompletionChoice ~ 1 + Order + Group * Phase + (1|Subject) + (1+Group+Phase|Item)
* Significant at $p < .05$; ** significant at $p < .01$; *** significant at $p < .001$

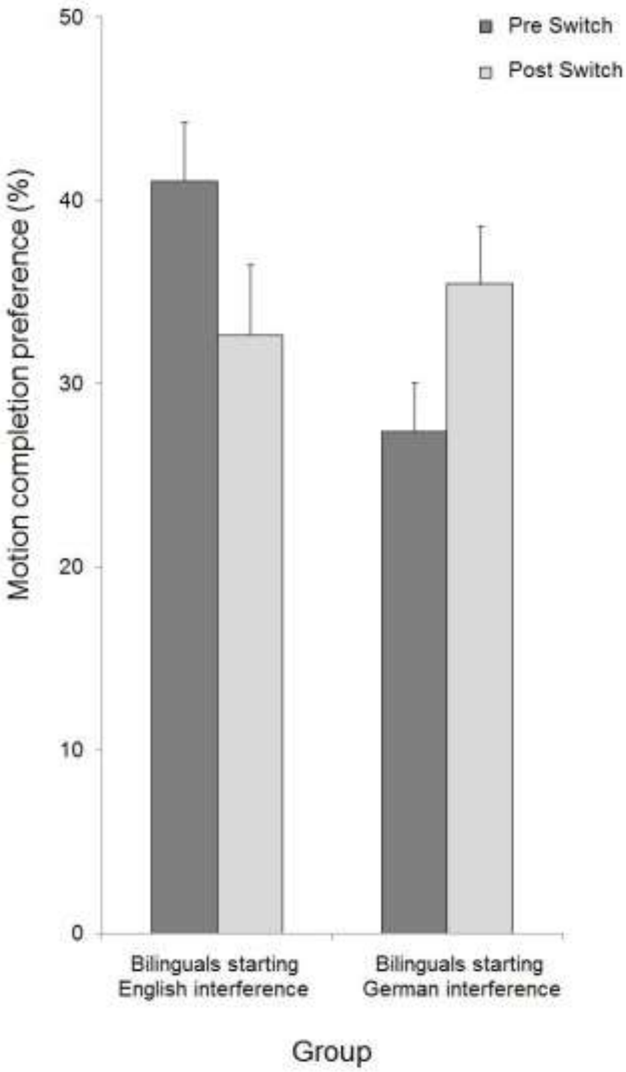

Figure 3. Motion completion preferences (%) pre- and post-language switch in Experiment 2 (varying language of verbal interference). Columns show group means. Error bars show standard error of the mean.

To aid interpretation of the interaction reported above, a follow-up analysis compared motion completion preferences of bilinguals only in the pre-switch phase, with those of English and German monolinguals under verbal interference. This was done in order to substantiate empirically the interpretation that interference in Language A does not only remove the influence of Language A on bilinguals' choices, but that it also allows the influence of Language B to affect the choices. Such interpretation would entail that bilingual behaviour to begin with (i.e., in the pre-switch phase) would be significantly different from monolingual behaviour under verbal interference. To this end, 15 German monolinguals (of comparable ages, educational and socioeconomic background as the bilinguals) additionally took the triads matching task under German verbal interference in Germany. English monolingual data were obtained from a random subset of 15 participants who took exactly the same task under English interference, reported in our previous study (Athanasopoulos & Bylund, 2013).

The proportion of motion completion preferences in German monolinguals under verbal interference was 33.9% (bilinguals under German interference: 26.7%) and in English monolinguals 32.8% (bilinguals under English interference: 40.4%). The binary dependent variable Completion choice (yes, no) was modelled using Bilingual Status (two levels: bilingual, monolingual), Language of Interference (two levels: German, English), and their interaction as predictors. The predictor Bilingual Status was centred. This was done because the number of observations between both groups differed, since it was only meaningful to include the pre-switch data for bilinguals. Further, the Order in which the item appeared (two levels: completion alternate first or second) entered the model as a fixed-effects nuisance factor so as to control for any effects it could have on completion choices. The random effects structure for the final model was determined as in the previous analysis. The final model included crossed random intercepts by subject and item, and by-item random slopes for Bilingual Status and Language of Interference. Collinearity was not an issue in this model (all fixed effect correlations $|r| < 0.1$; for all predictors VIF < 1.02).

Fixed effects from the final model are reported in

Table 1. The negative intercept again indicates that participants showed an overall preference for ongoingness, rather than completion alternates. The significantly positive coefficient for Order (a nuisance factor) indicates that participants were more likely to choose the completion alternate if it appeared second, rather than first. The absence of a main effect of Bilingual Status reflects that monolinguals and bilinguals did not differ in their likelihood to choose completion alternates. Crucially, the significantly negative coefficient for the interaction between Bilingual Status and Language of Interference indicates that this difference was driven by the bilingual speakers: among bilingual speakers only, German interference led to less completion choices and English interference led to more completion choices.

Table 1
Fixed effects from final mixed logit model of likelihood to choose a completion alternate in log-odds space.

Effect	Estimate	*S.E.*	Wald *Z*
Intercept	-0.80	0.18	-4.54 ***
Order (completion second vs. first)	0.11	0.05	1.99 *
Bilingual Status (Bilingual vs. Monolingual)	-0.04	0.14	-0.28
Language of Interference (German vs. English)	-0.12	0.07	-1.66
Bilingual Status × Language of Interference	-0.35	0.13	-2.73 **

Interactions that do not appear in this model did not significantly improve the fit. Formula in R: CompletionChoice ~ 1 + Order + BilingualStatus * LanguageOfInterference + (1 | Subject) + (1 + BilingualStatus + LanguageOfInterference | Item)
* Significant at $p < .05$; ** significant at $p < .01$; *** significant at $p < .001$.

Discussion and conclusions

Modern versions of the hypothesis that language shapes our thinking assume that the way objects and events are encoded in language may have immediate consequences for the way in which they are categorized (Lucy, 1997; Wolff & Holmes, 2010). The process of categorisation is commonly considered to operate on the basis of similarity, such that two stimuli that are perceived as similar are likely to be classified as members of the same category (Nosofsky, 1986). Our findings show that the dominant preference regardless of the operating language was for motion ongoingness. This is because all clips showed ongoing locomotion, and in both the ongoingness alternate and the target the endpoint was not reached (cf. Athanasopoulos & Bylund, 2013). However, we also show that language of operation and verbal interference systematically bias this preference, revealing online modulation of selective effects of language on human categorization, even on a very short time-scale. The finding that bilinguals exhibited categorization patterns of the non-interfered language shows that verbal interference does not reduce access to the general language faculty but only to a specific language. It is also evidence for the deployment of the conceptual repertoire of the non-active language during linguistic encoding.

Our results are compatible with findings showing short-term effects of novel category learning in different language contexts (Dolscheid, Shayan, Majid & Casasanto, 2013; Kersten, Meissner, Lechuga, Schwartz, Albrechtsen & Iglesias, 2010), with neural plasticity in categorical perception in the longer term (Athanasopoulos, Dering, Wiggett, Kuipers & Thierry, 2010), and with research showing that bilingual individuals' opinions of different ethnic groups are affected by the language in which they take a test probing their biases and predilections (Ogunnaike, Dunham & Banaji, 2010). Together, these findings strengthen the idea of a highly adaptive, flexible human conceptualization system (Barsalou, 2009; Casasanto & Lupyan, in press). We conclude that the state of such system at any given time is critically dependent on the language of operation.

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