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Should I focus on self-language actions or should I follow others? Cross-language interference effects in voluntary and cued language switching

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ABSTRACT

We examined whether and how language produced by others influences self-language processes. This study addressed this issue by looking at effects of comprehension on language switching in cued and voluntary switching contexts. During voluntary language switching, Chinese-English bilinguals were more likely to repeat the language they previously used themselves than to repeat the language produced by others. Furthermore, during both voluntary and cued language switching, bilinguals showed larger switch costs when switching between languages themselves than when switching after hearing another language. This suggests that cross-language interference may primarily stem from the self-language system rather than from language produced by others.

1. Introduction

In daily-life communication, we need to produce language ourselves ('self-language') and process language produced by others. This requires focusing on one's own language and the relevant information produced by others while also filtering out any irrelevant background noise. Thus, the interaction between people requires switching between production and comprehension. This kind of interaction can be regarded as a kind of joint action in which joint attention connects the speaker and listener (Peeters et al., 2020).

In addition to having to switch between production and comprehension, bilinguals need to control two languages and might need to switch between languages. The two languages of a bilingual might be activated in parallel and might interfere with each other (Dijkstra & Van Heuven, 2002; Giezen et al., 2015; Starreveld et al., 2014; van Heuven, Dijkstra, & Grainger, 1998; Van Heuven et al., 2008). The vast majority of research on bilingual language control has focused on words produced in isolation and/or in one modality only (i.e., either production or comprehension). Little is known about how bilinguals produce and comprehend language in a dialogue and how language production and comprehension interact. How might language produced by others influence a bilingual's own production and language switching?

The Interactive Alignment Model (Garrod & Pickering, 2009; Pickering & Garrod, 2004) states that the influence of external speech information on self-language processes can be interpreted as a type of priming during a dialogue. That is, various levels of linguistic representations (e.g., semantic, syntactic, lemma, phonology, etc.) are aligned between the speaker and listener during a dialogue. Studies examining language choice during dialogues between bilinguals have indeed shown that the interlocutor's language choice and moment of switching can prime the speaker's language choice and switching (e.g., Kootstra, Van Hell, & Dijkstra, 2010; Kootstra, Dijkstra, & Van Hell, 2020). Focusing on online measures (i.e., the processing cost associated with language production), Peeters et al. (2014) asked French-English bilinguals to name pictures in one language. Prior to naming a picture, participants had to make a language or categorization decision on a word presented in either French or English. When naming in French (but not in English), production was slower when the preceding word was presented in the other language, showing the (partial) presence of cross-modal switch costs. These cross-modal costs from comprehension to production were also observed by Gambi and Hartsuiker (2016), but this time participants did not complete an additional task during

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comprehension trials, thus reducing the potential influence of task effects. They conclude that the mechanisms used for bilingual language control are shared between comprehension and production and that bottom-up factors related to the actual language input can shape both comprehension and production.

However, top-down control too is likely to play a role in bilingual dialogues. Liu et al. (2019) used dual electroencephalogram (EEG) recordings to assess neural synchronization during cooperative picture-naming in either a bilingual's first language (L1) or second language (L2), and found that bilingual speakers and listeners achieved mutual understanding by inhibiting interference from the non-target language (cross-language interference) and partner (cross-person interference).

Studies examining switch costs from comprehension to production (e.g., Gambi & Hartsuiker, 2016; Peeters et al., 2014) have interpreted their findings in relation to the language nodes presented in the Bilingual Interactive-Activation (BIA) model (Dijkstra & Van Heuven, 1998). In this model, lexical entries are connected to language nodes. They can be activated through excitatory connections from the language node they belong to and/or suppressed through inhibitory connections from the "other" language node. Language nodes can be activated through bottom-up exogenous factors such as the actual language input as well as top-down endogenous factors such as contextual information requiring the choice of a specific language. Comprehension and production might differ in the way more exogenous versus endogenous factors influence language control and switching (Grainger et al., 2010). In comprehension, the presentation of a word in a specific language might activate language nodes and trigger the inhibition of words in another language (bottom-up mechanisms). In production, top-down control might be employed to inhibit words in the "other" language to ensure production in the target language. Despite the use of more bottom-up versus more top-down influences on language nodes, the assumption that these nodes are modality independent can explain why comprehension might influence language production.

However, recent studies have questioned whether language comprehension and production use (completely) overlapping mechanisms. First, Declerck et al. (2019) showed switch costs in non-linguistic and in language-production switching tasks but not during language comprehension. The different patterns in production versus comprehension tasks could suggest that different mechanisms are at play. This is in line with neuroimaging research (Blanco-Elorrieta & Pylkkänen, 2016) showing that different neural circuits are involved during switching in comprehension versus production. Furthermore, recent fMRI research (Liu, Kong, de Bruin, Wu, & He, 2020) showed a neural switch cost when going from comprehension to production (i.e., modality switching) and a neural cost when switching languages within the modality of production but not when switching languages from comprehension to production.

Thus, it remains an open question if and how language produced by others affects our own language production. Furthermore, some previous studies that show effects of comprehension on production (e.g., Gambi & Hartsuiker, 2016; Peeters et al., 2014) have focused on production in one language. Here we aimed to assess not just the potential influence of switching languages from comprehension to production but also how language switches between modalities compare to language switches within the same modality (i.e., production). We therefore compared within- and cross-speaker conditions. In the within-speaker conditions (i.e., when a bilingual produces language themselves), cross-language interference stems from the speaker. In the cross-speaker condition (i.e., when self-language production is preceded by another speaker), interference can stem from language produced by others too. Within each condition, the first (L1) and second (L2) language had to be used, leading to repeat trials (the same language on several consecutive trials) or switch trials (two different languages on two consecutive trials).

Generally, switch trials lead to longer reaction times than repeat trials, producing the so-called switch costs. According to the Inhibitory Control (IC) model more inhibition of the highly activated L1 will be recruited when switching to the less strongly activated L2 (Green, 1998). Subsequently, switching back to L1 is argued to take more time to release previous inhibition. Thus, switches to L1 will take longer than switching to L2 (i.e., asymmetrical language switch costs) which is treated as an indication of inhibitory control (Costa et al., 2006; Costa & Santesteban, 2004; Liu et al., 2016; Meuter & Allport, 1999; Philipp et al., 2007; Philipp & Koch, 2009).

These language-switch costs have typically been studied in cued switching tasks in which bilinguals are instructed to use a specific language. This type of context resembles the dual-language context in the Adaptive Control Hypothesis (Green & Abutalebi, 2013) in which language switching requires constant monitoring of the circumstances in order to select the appropriate language and as such is argued to require a relatively high level of language control. However, bilinguals are argued to require less control when they switch languages in the so-called 'dense code-switching' environment, which allows bilinguals to switch freely and can use more bottom-up mechanisms by choosing the more accessible word regardless of the language (e.g., de Bruin et al., 2018; Gollan & Ferreira, 2009; Gollan, Kleinman, & Wierenga, 2014; Gross & Kaushanskaya, 2015; Jevtović et al., 2020; Kleinman & Gollan, 2016). This switching context might pose lower demands on cognitive processes such as goal maintenance, cue detection, and response inhibition.

To better examine the interplay between language control during comprehension and production, we studied both cued and voluntary language switching during production. Research has suggested that more language control is needed during cued than voluntary language switching (e.g., Blanco-Elorrieta & Pylkkänen, 2017; de Bruin et al., 2018; Green & Abutalebi, 2013; Jevtović et al., 2020). Focusing on the switch costs, results are more mixed. Some studies have observed switch costs during voluntary as well as cued switching (e.g., de Bruin et al., 2018; Gollan, Schotter, et al., 2014), suggesting that although lexical access participates in voluntary language switching, the role of top-down control should not be ignored. Others have found that voluntary switch costs might be smaller than cued costs (e.g., Jevtović et al., 2020), absent (e.g., Blanco-Elorrieta & Pylkkänen, 2017), or dependent on how bilinguals are instructed to use their languages (Kleinman & Gollan, 2016). These findings suggest that top-down control might be needed during both cued and voluntary switching, but that the latter might also be driven by bottom-up mechanisms related to lexical access.

In the current study we thus studied if and how comprehension and production influence each other during language switching in voluntary (Experiments 1 and 2) and cued (Experiment 3) switching contexts. We included within-person trials in which production was preceded by another production trial produced by the speaker themselves and cross-person trials in which the speaker's production trial was preceded by a comprehension trial produced by another person. In line with daily-life communication that does not always require explicit responses to spoken input, Experiment 1 asked participants to just listen to words without giving a response. Next, to make sure that participants paid attention to the spoken input, Experiment 2 required them to make explicit responses to the words they heard. Lastly, we examined how language influenced by others affects the top-down mechanisms involved in cued switching (Experiment 3).

Within the voluntary task, we examined whether language switching was affected by the language previously heard. If speech produced by others has a smaller influence on our own language production than our own language behaviour, more language repetitions should be produced in the within-person condition (i.e., lower switching frequency on a production trial preceded by another production trial) than in the cross-person condition (i.e., higher switching frequency on a production trial preceded by a comprehension trial).

In all tasks, we examined language-switch costs within the production modality and between modalities when switching from comprehension to production. If similar mechanisms are involved in language control during comprehension and production, we expect language-switch costs to occur both in within-person and in cross-person conditions. However, if different mechanisms are used (with comprehension relying more on bottom-up factors and production on top-down control), we would expect different language-switch cost patterns in the within- and cross-person conditions.

2. Experiment 1: voluntary language switching

2.1. Methods

2.1.1. Participants

A total of 34 healthy volunteers from Liaoning Normal University participated in this study, all of them were right handed with normal or corrected-to-normal vision and no history of neurological or psychological impairments or receiving treatment with any psychoactive medication. Four participants were eliminated from the analysis because they used one naming language all the time, meaning that they produced no switch trials. The final sample consisted of 30 participants (5 male; *M*age = 22, *SD*age = 2). All participants signed written informed consent. The research protocol was approved by the Institutional Review Board at the School of Psychology, Liaoning Normal University.

The participants' native language was Chinese (L1) and they used English as their second language, having studied English (L2) for an average of 12 years. To assess their language proficiency, we used the Oxford Placement Test (OPT, maximum score 50 points; Allan, 2004) and a questionnaire asking about self-rated language skills (see Table 1). The participants' average score of 36 points on the OPT resembles previous studies testing Chinese—English unbalanced bilinguals with intermediate L2 proficiency (e.g., Liang & Chen, 2014; Liu et al., 2016). The self-ratings were provided using a six-point scale in which "6" indicated that L1/L2 knowledge were perfect, and "1" indicated no knowledge of L1/L2. Paired sample *t*-tests showed that the proficiency ratings were significantly higher for L1 than L2: listening, $t(29) = 10.46$, $p < .001$; speaking, $t(29) = 8.83$, $p < .001$; reading, $t(29) = 7.56$, $p < .001$; writing, $t(29) = 5.72$, $p < .001$. Thus, the participants were unbalanced bilinguals with weaker proficiency in L2 than in L1.

2.1.2. Materials

Forty-eight black and white line drawings were selected from the Snodgrass and Vanderwart's photo gallery as picture naming stimuli, which were standardized by Zhang and Yang (2003). Each Chinese name consisted of two characters, and their English name consisted of one or two syllables with three to six letters. Forty bilinguals who did not participate in this experiment rated the subjective familiarity of Chinese and English words on a 5-point scale (1 = "very unfamiliar", 5 = "very familiar"). There were no significant differences between subjective Chinese name familiarity and subjective English name familiarity (L1: 4.79 ± 0.12, L2: 4.81 ± 0.10, $t(47) = -1.48$, $p > .05$) nor between Chinese word frequency and English word frequency (L1: 77.53 ± 114.24, L2: 104.23 ± 128.39, $t(47) = 1.54$, $p > .05$) (Chinese word frequency: Cai & Brysbaert, 2010; English word frequency: Brysbaert & New, 2009).

We invited a Chinese female volunteer with high proficiency in English to record the Chinese and English names of the 48 pictures used in the experiment. All collected sound materials were clear and accurate.

Table 1
Participants' characteristics.

Self-rating	Experiment 1		Experiment 2		Experiment 3	
	L1	L2	L1	L2	L1	L2
Listening	5.42 (0.72)	3.52 (0.81)	5.29 (0.86)	3.29 (0.94)	5.54 (0.64)	3.53 (0.79)
Speaking	4.88 (0.76)	3.32 (0.83)	5.03 (0.71)	3.26 (0.58)	5.04 (0.43)	3.46 (0.74)
Reading	4.42 (1.20)	2.94 (1.12)	4.42 (1.02)	3.32 (1.17)	4.54 (1.20)	3.04 (1.20)
Writing	4.80 (0.98)	3.10 (1.27)	4.77 (1.28)	3.13 (1.06)	5.00 (0.90)	3.21 (1.07)
OPT		35.84 (4.48)		36.52 (3.94)		36.75 (4.0)

2.1.3. Procedure

Participants were familiarised with all pictures before the experiment. Audio recordings of a Chinese-English speaker were used to build the cross-person condition. Participants thus either named a picture themselves or listened to an audio recording of the word, thus forming the two modalities of production and comprehension. Speaker repetitions across two or more consecutive trials (either production or comprehension) formed part of the within-person condition. If the speaker switched from comprehension to production or vice versa on two consecutive trials, the trial belonged to the cross-person condition. In the analysis, we focused on production trials, which were either within-person (production – production) or cross-person (comprehension – production).

In addition, two consecutive trials could be named or listened to in the same language or in different languages, leading to Repeat and Switch trials. In the Within-production condition, cross-language interference just stems from the self-language system, while in the Cross-person condition, potential cross-language interference could also stem from language produced by others.

In the voluntary picture naming task, participants had to name the picture or listen to a response depending on a cue reminding the participants when to listen or to speak. For example, when a picture with a white square appeared on the screen, the participant had to name the picture, using the language that came to mind first when they saw a picture. Upon seeing a white circle around a triangle, the participant had to listen carefully to the recorded name. To ensure that participants fully understood the task, there were 20 practice trials prior to the formal experiment. The formal experiment consisted of 6 blocks and each block had 2 preliminary trials and 96 trials. An additional ten pictures were used in the practice task and 2 warm-up trials were used before each block started. The selected 48 pictures were used for the formal experiment and appeared once in each block. Language (L1, L2), Trial type (Repeat, Switch) and Person sequence (Within-person, Cross-person) were the three within-subject factors we focused on. All conditions were presented in a pseudo-random order so that participants did not know whether the next trial was going to be production or comprehension and L1 or L2. In the Within-person comprehension trials, each condition had been arranged in a pseudo-random order, with each condition (Language × Trial type) having 36 trials. We focused on behavioral performance (i.e., naming onset times) during language production trials, for which we collected a total of 288 trials for each participant (144 Within-person trials and 144 Cross-person trials).

Each trial started with the presentation of a fixation cross for 250 ms, then a blank screen for 500 ms, followed by a picture with a cue. The pictures were presented on the screen and disappeared after a spoken response was made or after 1500 ms. Participants were asked to name the pictures aloud while avoiding hesitations and their responses were recorded. The next trial was presented after the interval of 1000 ms (see Fig. 1).

To ensure that the participants listened carefully to the names during the experiment, we reminded them in the instructions and set simple judgement questions after they finished each block. The question presented participants with a Chinese or English word and asked them to indicate whether they had heard the word during the task. A total of 12 words were presented for judgement. Half of the words had appeared in the task and half had not. If they thought "Yes", they had to press '1', otherwise they had to press '2'.

2.1.4. Analysis

During the picture naming task, the research assistants coded the

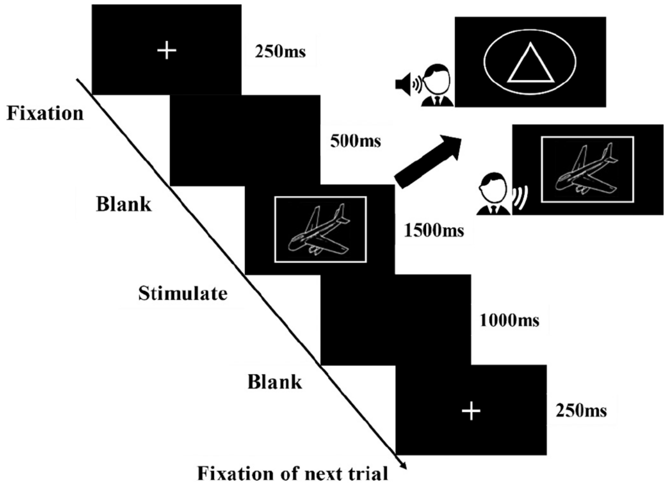

Fig. 1. Illustration of the experimental procedure. Participants had to listen carefully when they just saw the white circle around a triangle (Cross-person); they had to name the picture when they saw the white square surrounding the picture (Within-person). Participants sometimes had to use the same language (L1 or L2) continuously (Repeat), or they had to switch from one language to another (Switch).

participants' responses in real time. Error responses in Experiment 1 were coded as follows: A) no response; B) wrong word (name that did not match the picture); C) using two languages for the same picture; D) a trial after an error response. Furthermore, data from the first two trials of each block and the naming latencies beyond $M \pm 3SD$ per participant were also excluded. Since the response language in the voluntary picture naming task was free, there was no correct or incorrect language. In total, about 4.8% of the total data (8640 trials) were excluded, leaving on average 274 trials per participant (Mean number of trials in Within-person condition: 51 L1 repeat, 12 L1 switch, 60 L2 repeat, 15 L2 switch; in Cross-person condition: 34 L1 repeat, 32 L1 switch, 39 L2 repeat, 32 L2 switch). Furthermore, the average accuracy of the simple judgement questions was 56%. It should be noted that the purpose of the questions was to encourage the participants to listen carefully to the word but without interfering with their normal naming response. We therefore did not ask them to memorise the heard words, which could explain the low judgement score.

Naming latencies were skewed, so we first log transformed them before analyzing them with linear mixed-effect models in R (R version 4.0.2) using the lme4 package (lme4 version 1.1–23, Bates et al., 2014) and lmerTest package (Kuznetsova et al., 2017). Apart from fixed effects, the models included participants and items as random effects (random intercepts and slopes). When models did not converge, we removed the slope that explained the least variance until the model converged. Results from the best-fitting model justified by the data were reported. Parameters were estimated with Restricted Maximum Likelihood (REML), and we reported the full models including all fixed effects, including the nonsignificant ones.

We started with a model of voluntary language switching using log naming latencies as the dependent variable (DV) and Language, Trial type, and Person sequence as fixed effects. The best-fitting model structure included random intercepts for participants and items and Language and Person sequence were included as a by-subject slope and by-item slope. All fixed effect factors were two-level categorical predictors and coded as −0.5 and 0.5. For the factor Language, L1 was coded as −0.5 and L2 as 0.5; for the Trial type, Repeat was coded as −0.5 and Switch as 0.5; for Person sequence, Within-person was coded as −0.5 and Cross-person as 0.5. In addition, we examined whether switching frequency differed between the Within- and Cross-person conditions using a logistic mixed-effects model. In this analysis, Trial type was included as the DV (Repeat trials were coded as 0, Switch trials were coded as 1), Language and Person sequence were included as fixed effects. All models converged. The reported p values were adjusted with Bonferroni correction.

2.2. Results

2.2.1. Switching frequency results

We calculated the frequency of switching languages in the voluntary task (see Fig. 2). The frequency of language switching was much lower in the Within-person condition than in the Cross-person for both languages. In the L1 Within-person condition, the average switching percentage was 22 ± 13 and the average percentage in the L2 Within-person condition was 23 ± 14. In contrast, in the Cross-person condition, average L1 switching was 48 ± 7 and 44 ± 6 in the L2 Cross-person condition. This lower switching frequency in the within-person condition reflects that participants were more likely to repeat the previous language when it was produced by themselves than they were to repeat the language produced by another speaker.

We examined whether switching frequency differed significantly between the Within- and Cross-person conditions and between the L1 and L2 (see Table 2). In this analysis, a trial was defined as a switch if the current language differed from the previous trial. In the cross-person condition, this previous trial was a comprehension trial. Only Person sequence had a significant main effect, showing that the switching percentages were indeed lower in the Within-person ($M = 23$, $SD = 13$) than in the Cross-person condition ($M = 46$, $SD = 7$). Participants were more likely to repeat the language when the previous trial was an own-production trial.

2.2.2. Language switching naming latencies results

Table 3 and Fig. 3 show the voluntary language switching results. The main effect of Trial type was significant, with longer naming latencies in Switch trials ($M = 775$ ms, $SD = 159$ ms) compared to those in Repeat trials ($M = 747$ ms, $SD = 145$ ms). The main effect of Person sequence was significant, with longer naming latencies in the Within-person trials ($M = 758$ ms, $SD = 151$ ms) compared to those in the Cross-person trials ($M = 754$ ms, $SD = 149$ ms). This was entirely driven by the switch trials, as reflected by the interaction between Trial type × Person sequence. This interaction was of main interest because it reflects differences in switch costs between the Within- and Cross-person conditions. Naming latencies in Switch trials ($M = 825$ ms, $SD = 170$ ms) were longer than those in Repeat trials ($M = 741$ ms, $SD = 142$ ms) in the Within-person condition ($\beta = -0.09$, $SE = 0.01$, $t = -12.93$, $p < .001$), but not in the Cross-person condition (Switch: $M = 753$ ms, $SD = 149$ ms; Repeat: $M = 755$ ms, $SD = 150$ ms, $\beta = 0.01$, $SE = 0.01$, $t = 0.59$, $p = .56$). These findings indicate that language produced by others did not influence self-language production (i.e., there was no switch cost when switching languages from comprehension to production). This pattern did not interact with Language. In both L1 and L2 Within-person switch costs were larger than Cross-person switch costs (L1 within: $M = 90$ ms, $SD = 85$ ms versus L1 cross: $M = 11$ ms, $SD = 43$ ms; L2 within: $M = 46$ ms, $SD = 56$ ms versus L2 cross: $M = -13$ ms, $SD = 21$ ms, see Fig. 4). These findings indicate that cross-language interference might mainly stem from the self-language system in both languages.

The interaction between Language × Trial type reached significance, reflecting larger switch costs in L1 than L2 (see Fig. 4). Follow-up analyses revealed that L1 naming latencies ($M = 785$ ms, $SD = 174$ ms) were slightly longer than L2 naming latencies ($M = 765$ ms, $SD = 142$ ms) in Switch trials ($\beta = 0.02$, $SE = 0.01$, $t = 1.86$, $p = .06$), but L1 naming latencies ($M = 750$ ms, $SD = 158$ ms) did not differ from L2 ($M = 743$ ms, $SD = 133$ ms) in Repeat trials ($\beta = -0.01$, $SE = 0.01$, $t = -0.28$, $p = .78$) (see Fig. 3). Despite the switch cost being larger for L1 than L2, there was a significant switch cost in both L1 ($\beta = -0.05$, $SE = 0.01$, $t = -8.56$, $p < .001$) and L2 ($\beta = -0.03$, $SE = 0.01$, $t = -4.57$, $p < .001$). The interaction between Language × Person sequence also reached significance, indicating that L1 naming latencies ($M = 768$ ms, $SD = 166$ ms) were

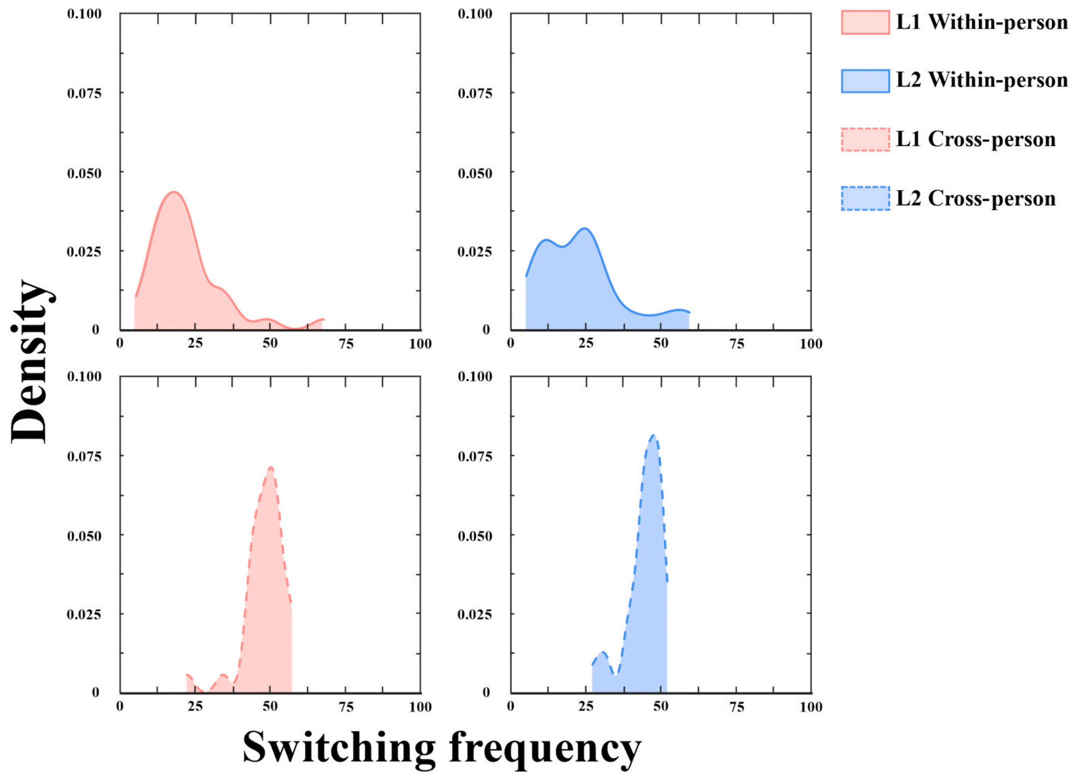

Fig. 2. Density plots showing the distribution of the switching percentages across participants in each condition. The density is the total number of trials divided by the number of switch trials, i.e., density = Switch trials/Total trials. The area under the curve between point A and B (e.g., 30–45%) reflects the probability of a value falling between those points A and B (with the total area under the curve being 1).

Table 2
Logistic mixed-effect model of voluntary language switching rate in Experiment 1.

Predictor		β	*SE*	Contrast	
				z	*p*
Fixed effects					
Intercept		−0.88	0.06	−15.95	<0.001***
Language		−0.01	0.26	−0.03	>0.99
Person		**1.53**	**0.10**	**15.55**	**<0.001*****
Language × Person		−0.09	0.12	−0.71	0.91
Random effects		*Variance*	*SD*	*Corr*	
Item	Intercept	0.004	0.06		
	Language	3.07	1.75	−0.67	
Subject	Intercept	0.06	0.25		
	Language	0.07	0.27	0.37	
	Person	0.19	0.44	−0.98	−0.37

Note: Results of best-fitting logistic mixed effects model of voluntary language switching rate, Trial type as DV (Repeat trials were coded as 0, Switch trials were coded as 1). Fixed-effect predictors: Language (L1 trials were coded as −0.5, L2 trials were coded as 0.5), Person sequence (Within-person −0.5, Cross-person 0.5). Random effects by subjects: intercept, Language slope, Person sequence slope. Random effects by items: intercept, Language slope. For each predictor, the estimate, standard error, *z* values and *p* values are given. Asterisks indicate a significant effect. *** indicates $p < 0.001$, **indicates $p < 0.01$, * indicates $p < 0.05$.

Table 3
Mixed-effects model of voluntary language switching for naming latencies in Experiment 1.

Predictor		β	*SE*	Contrast	
				t	*p*
Fixed effects					
Intercept		6.63	0.02	426.81	<0.001***
Language		−0.01	0.01	−0.90	0.97
Trial type		**0.04**	**0.004**	**9.61**	**<0.001*****
Person		**−0.03**	**0.01**	**−2.77**	**0.04***
Language × Trial type		**−0.03**	**0.01**	**−3.10**	**0.02***
Language × Person		**0.03**	**0.01**	**2.88**	**0.03***
Trial type × Person		**−0.09**	**0.01**	**−10.39**	**<0.001*****
Language × Trial type × Person		0.01	0.02	0.30	>0.99
Random effects		*Variance*	*SD*	*Corr*	
Item	Intercept	0.003	0.05		
	Language	0.001	0.03	−0.29	
	Person	0.002	0.05	−0.10	0.16
Subject	Intercept	0.005	0.07		
	Language	0.003	0.05	−0.23	
	Person	0.001	0.03	0.13	−0.14

Note: Results of best-fitting mixed effects model of voluntary naming latency, using log naming latencies as DV. Fixed-effect predictors: Language (L1 −0.5 and L2 0.5), Trial type (Repeat −0.5 and Switch 0.5), Person sequence (Within-person −0.5 and Cross-person 0.5). For each predictor, the estimate, standard error, *t* values and *p* values are given. Asterisks indicate a significant effect. Random effects by subjects: intercept, Language slope, Person sequence slope. Random effects by items: intercept, Language slope, Person sequence slope.

slightly longer than L2 ($M = 749$ ms, $SD = 138$ ms) in the Within-person condition ($\beta = 0.02$, $SE = 0.01$, $t = 1.81$, $p = .07$), but L1 naming latencies ($M = 757$ ms, $SD = 163$ ms) did not differ from L2 ($M = 752$ ms, $SD = 135$ ms) in the Cross-person condition ($\beta = -0.01$, $SE = 0.01$, $t = -0.18$, $p = .86$). Further, naming latencies in the Within-person condition were longer than those in the Cross-person condition ($\beta = -0.04$, $SE = 0.01$, $t = 3.67$, $p < .001$) in L1 trials, while there was no difference between the Within- and Cross-person conditions in L2 trials ($\beta = 0.01$, $SE = 0.01$, $t = 1.31$, $p = .19$).

2.3. Discussion

First, during voluntary language switching, we found that participants were much more likely to switch languages in the cross-person

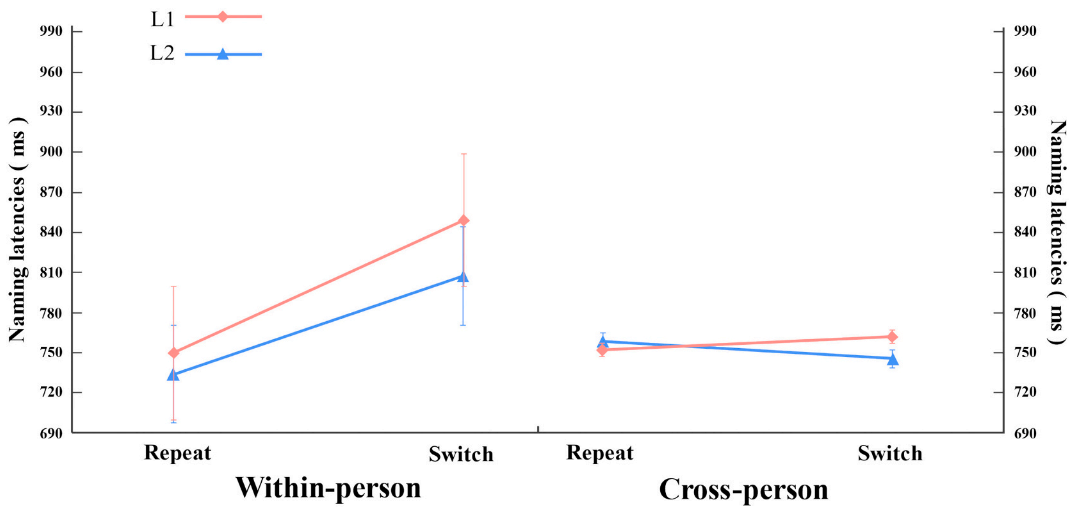

Fig. 3. Naming latencies in the voluntary language switching task (Experiment 1), using the original reaction times. Left and right panels show the mean naming latencies of Trial type (repeat and switch) by Language (L1, L2) in the within- and cross-person condition, respectively. Error bars for naming latencies show standard errors of naming latencies across subjects calculated separately for each level.

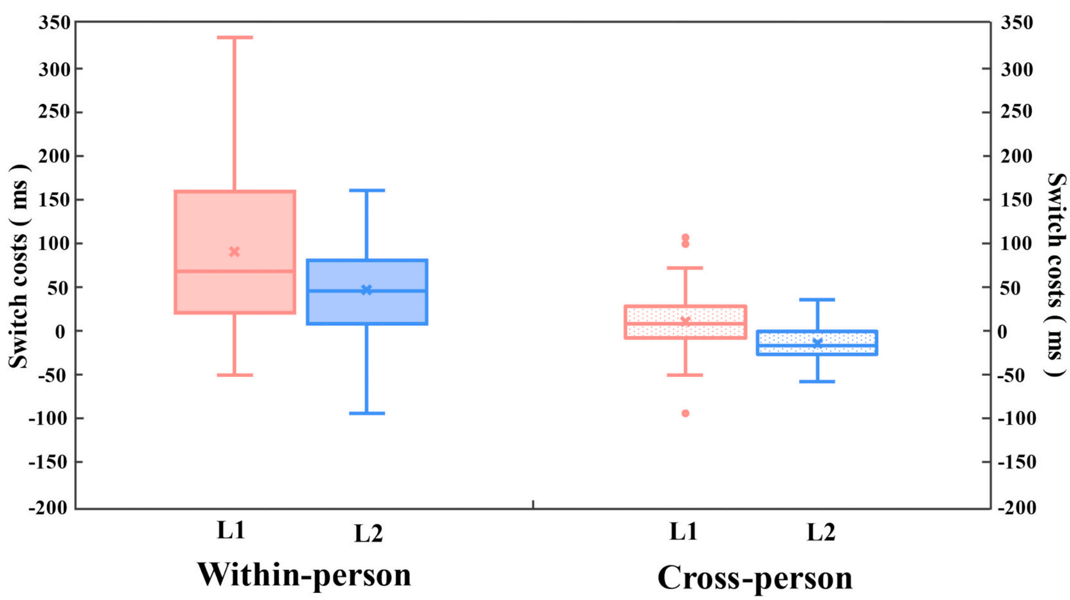

Fig. 4. Language switch costs in the within- and cross-person conditions. The boxes for switch costs are the upper and lower quartiles, the bars represent upper and lower edges, and the lines in the boxes show medians, the crosses represent the mean, the dots show outliers.

than in the within-person condition. This suggests that the language produced by others does not influence our own language choice as much as our own previously produced language does (i.e., bilinguals were less likely to repeat the language used by the other person than they were to repeat the language they just used themselves). Second, language switch costs during the within-person condition were larger than those during the cross-person condition. This finding again suggests that switch costs are mainly driven by the self-language system, while language produced by others might be less influential.

In addition, overall response times were longer in the Within-person condition than the Cross-person condition. This was entirely driven by the longer switch naming latencies in the Within-person condition. In addition, these longer naming latencies were only observed for L1 trials, in line with larger switch costs when switching to L1 than to L2. We will return to these language-specific patterns in the General Discussion.

To summarize, the results of Experiment 1 indicated that participants did not show an influence of language comprehension on language production. As an attention check, we asked participants after the task to indicate whether they had previously heard the words that were presented during comprehension trials. Mean performance on this judgement task was low, which could suggest that participants were not paying sufficient attention to comprehension trials. We therefore included an animacy judgement task in Experiment 2. This additional task required participants to process the words used during comprehension trials. This way, we could examine whether the results observed in Experiment 1 were indeed due to language comprehension having little influence on cross-language interference during production and not to participants simply ignoring the comprehension trials.

3. Experiment 2: voluntary language switching with judgement task

3.1. Methods

3.1.1. Participants

In total, 33 Chinese–English bilingual college students participated in Experiment 2, all of them were right handed with normal or corrected-to-normal vision and no history of neurological or psychological impairments or receiving treatment with any psychoactive medication. Two participants were eliminated from the analysis because they used one naming language all the time, meaning that they produced no switch trials. The final sample consisted of 31 participants (9 male; *M*age = 23, *SD*age = 2). All participants signed written informed consent. The research protocol was approved by the Institutional Review Board at the School of Psychology, Liaoning Normal University. Participants completed the OPT and the average score of the OPT was 37 (SD = 3.9). More detailed information about the participants can be found in Table 1. Paired sample *t*-tests revealed that the proficiency ratings were significantly higher for L1 than L2: listening, $t(30) = 11.13$, $p < .001$; speaking, $t(30) = 11.69$, $p < .001$; reading, $t(30) = 6.73$, $p < .001$; writing, $t(30) = 7.64$, $p < .001$. The OPT and self-rating scores indicate that participants in Experiment 2 were unbalanced bilinguals with weaker proficiency in L2 than in L1.

3.1.2. Materials

The same materials were used as in Experiment 1.

3.1.3. Procedure

The procedure of Experiment 2 was the same as the voluntary naming task in Experiment 1, with the addition of a judgement task after every comprehension trial. In Experiment 1, participants completed a simple judgement task at the end of each block. In contrast, in Experiment 2, participants were asked after each comprehension trial to judge whether the word they had just heard was animate (press "F") or inanimate (press "J"). This required participants to process and respond to the comprehension trials. Animate words such as animals, plants and human organs required an 'animate' response while other types of words were inanimate. Participants needed to make a judgement within 2000 ms.

3.1.4. Analysis

Naming data analysis was the same as in Experiment 1. About 8.3% of the total data (8928 trials) were incorrect responses or preceded by an error and were excluded, leaving on average 264 trials per participant (Mean number of trials in the Within-person condition: 35 L1 repeat, 14 L1 switch, 68 L2 repeat, 14 L2 switch; in the Cross-person condition: 25 L1 repeat, 24 L1 switch, 43 L2 repeat, 40 L2 switch).

In addition, we analyzed the judgement response in the comprehension trials to assess whether there were switch costs during comprehension. Error responses and responses beyond $M \pm 3SD$ were excluded, leaving 271 trials per participant on average. The linear mixed-effects model included Language, Trial type, Person sequence and their interaction as fixed effects and log judgement RTs as the DV. The fitted model included Subject and Item as random effects, and Language as the random slope for Subject. All fixed effects were two-level categorical predictors and coded as −0.5 and 0.5. The reported *p* values were adjusted with Bonferroni correction.

3.2. Results

3.2.1. Language comprehension trials

We first assessed responses on comprehension trials. First, we examined accuracy to ensure participants paid attention to comprehension trials. The average accuracy of the judgement task was 95% (Mean accuracy in the Within-person condition: 96% L1 repeat, 99% L1 switch, 93% L2 repeat, 94% L2 switch; in the Cross-person condition: 95% L1 repeat, 96% L1 switch, 95% L2 repeat, 91% L2 switch) and the average reaction time was 587 ms ($SD = 250$). The high judgement performance showed that participants paid attention to the comprehension trials and processed the words they heard.

Next, we examined whether there was a significant switch cost during comprehension trials. Finding a switching effect during comprehension would suggest that the absence of cross-person switch costs in production is not the result of bottom-up input during comprehension not being strong enough to create language interference. As seen in Table 4, there was a significant effect of Language indicating that the judgement responses in L1 ($M = 518$ ms, $SD = 228$ ms) were faster than in L2 ($M = 659$ ms, $SD = 251$ ms). The significant main effect of Person sequence showed that participants responded faster in the Within-person condition (comprehension preceded by comprehension) than in the Cross-person condition (comprehension preceded by production). The significant interaction between Language × Trial type revealed larger comprehension switch costs in L2 than in L1. In both the Within- and Cross-person condition, L2 repeat latencies (Within: $M = 629$ ms, $SD = 244$ ms; Cross: $M = 645$ ms, $SD = 243$ ms) were faster than L2 switch trials (Within: $M = 673$ ms, $SD = 252$ ms; Cross: $M = 697$ ms, $SD = 262$ ms; Within: $\beta = -0.08$, $SE = 0.02$, $t = -4.46$, $p < .001$; Cross: $\beta = -0.04$, $SE = 0.02$, $t = -2.54$, $p = .01$), showing an L2 switch cost. In contrast, L1 repeat naming latencies (Within: $M = 518$ ms, $SD = 225$ ms; Cross: $M = 547$ ms, $SD = 240$ ms) were slower than L1 switch trials (Within: $M = 491$ ms, $SD = 203$ ms; Cross: $M = 522$ ms, $SD = 240$ ms; Within: $\beta = 0.04$, $SE = 0.02$, $t = 2.43$, $p = .02$; Cross: $\beta = 0.04$, $SE = 0.02$, $t = 2.57$, $p = .01$). Thus, this analysis showed the presence of comprehension switch effects (with the direction depending on the language).

3.2.2. Switching frequency results

Fig. 5 shows the language switching frequency, and, similar to Experiment 1, this frequency was lower in the Within-person condition than in the Cross-person condition for both languages. The switching percentage on average was 38 ± 23 in the L1 Within-person condition, 25 ± 20 for L2 Within-person, 48 ± 8 for L1 Cross-person and 50 ± 6 for L2 Cross-person. Logistic mixed-effects models (see Table 5) showed that the switching percentages in the Within-person condition ($M = 22$, $SD = 13$) were lower than in the Cross-person condition ($M = 49$, $SD = 4$), in line with Experiment 1. The interaction between Language × Person sequence reached significance. Follow-up analyses revealed that in the Within-person condition, L1 switching rate was higher than L2

Table 4
Mixed-effects model for judgement responses in language comprehension.

Predictor		*β*	*SE*	Contrast	
				t	*p*
Fixed effects					
Intercept		6.30	0.47	135.00	<0.001***
Language		**0.27**	**0.04**	**7.54**	**<0.001*****
Trial type		0.01	0.01	1.25	0.85
Person		**0.06**	**0.01**	**7.67**	**<0.001*****
Language × Trial type		**0.10**	**0.02**	**6.08**	**<0.001*****
Language × Person		−0.03	0.02	−2.05	0.28
Trial type × Person		−0.02	0.02	−1.27	0.83
Language × Trial type × Person		−0.05	0.03	−1.35	0.79
Random effects		*Variance*	*SD*	*Corr*	
Subject	Intercept	0.06	0.24		
	Language	0.01	0.09	−0.42	
Item	Intercept	0.02	0.15		

Note: Results of best-fitting mixed effects model of the judgement response analysis, using log judgement responses as the DV. Fixed-effect predictors: Language (L1 −0.5 and L2 0.5), Trial type (Repeat −0.5 and Switch 0.5), Person sequence (Within-person −0.5 and Cross-person 0.5). For each predictor, the estimate, standard error, *t* values and *p* values are given. Asterisks indicate a significant effect. Random effects by subjects: intercept, Language slope. Random effects by items: intercept.

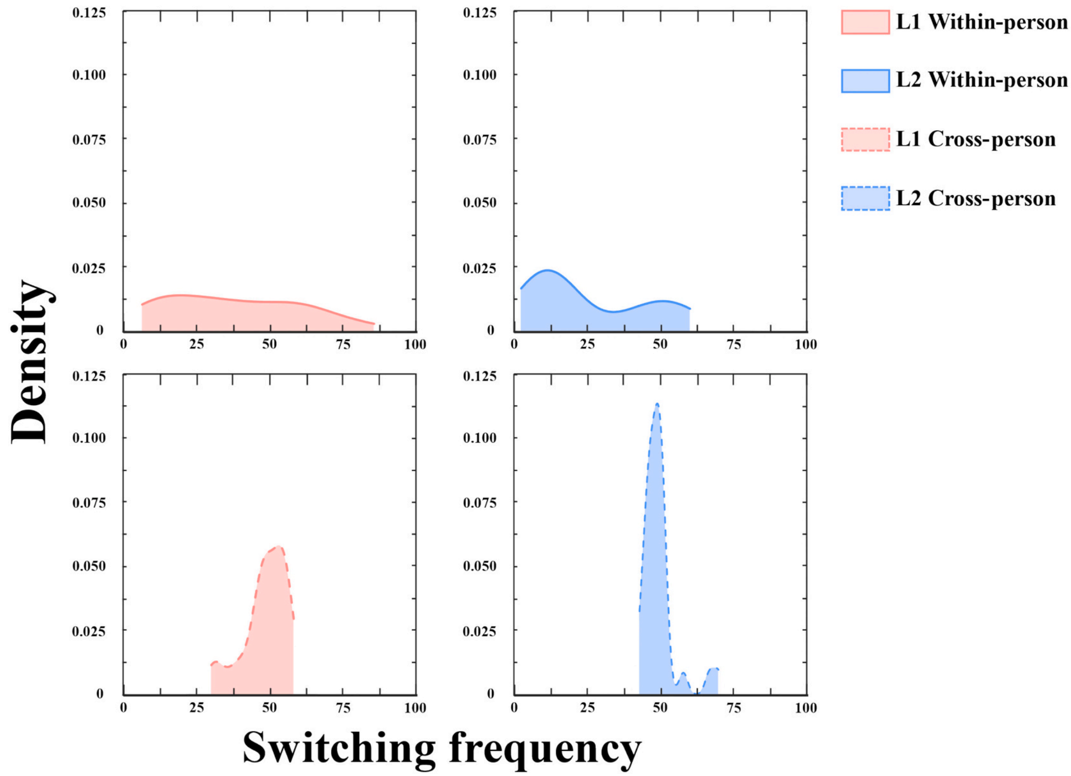

Fig. 5. Density plots showing the distribution of the switching percentages across participants in each condition. The density is the total number of trials divided by the number of switch trials, i.e., density = Switch trials / Total trials. The area under the curve between point A and B (e.g., 30–45%) reflects the probability of a value falling between those points A and B (with the total area under the curve being 1).

Table 5
Logistic mixed-effect model of language switching rate in Experiment 2.

Predictor		β	*SE*	Contrast	
				z	*p*
Fixed effects					
Intercept		−0.67	0.08	−8.85	<0.001***
Language		−0.45	0.30	−1.50	0.40
Person		**1.56**	**0.17**	**9.29**	**<0.001*****
Language × Person		**0.88**	**0.14**	**6.34**	**<0.001*****
Random effects		*Variance*	*SD*	*Corr*	
Item	Intercept	0.01	0.11		
	Language	3.32	1.82	0.83	
Subject	Intercept	0.13	0.36		
	Language	0.44	0.66	0.22	
	Person	0.75	0.87	−0.95	0.07

Note: Results of best-fitting logistic mixed effects model of the language switching rate in Experiment 2, with Trial type as DV (Repeat trials were coded as 0, Switch trials were coded as 1). Fixed-effect predictors: Language (L1 trials were coded as −0.5, L2 trials were coded as 0.5), Person sequence (Within-person −0.5, Cross-person 0.5). Random effects by subjects: intercept, Language slope, Person sequence slope. Random effects by items: intercept, Language slope. For each predictor, the estimate, standard error, *z* values and *p* values are given. Asterisks indicate a significant effect.

switching rate ($\beta = 0.88$, $SE = 0.31$, $z = 2.89$, $p = .004$), However, no such difference between languages was found in the Cross-person condition ($\beta = 0.01$, $SE = 0.30$, $z = 0.03$, $p = .98$). However, comparisons between Within- and Cross-person conditions per language showed that the switching rate in the Cross-person was higher than in the Within-person in both L1 ($\beta = -1.12$, $SE = 0.18$, $z = -6.05$, $p < .001$) and L2 ($\beta = -1.99$, $SE = 0.18$, $z = -11.21$, $p < .001$). In Experiment 2, we added a judgement task after each trial to make sure that participants paid attention to the comprehension trials. Still, and in line with Experiment 1, switching frequency was lower in the Within-person than Cross-person condition, suggesting that participants were more likely to follow the previously used language when it was used by themselves than when it was used by another person. To examine whether the difference between the Cross- and Within-person condition was smaller when participants had to pay more attention to comprehension trials, we compared switching frequency results across the two experiments.

Table 6 shows the results from the model comparing switching

Table 6
Logistic mixed-effect model of language switching rate in Experiment 1 vs. 2.

Predictor		β	*SE*	Contrast	
				z	*p*
Fixed effects					
Intercept		−0.82	0.04	−19.73	<0.001***
Language		−0.23	0.26	−0.89	0.98
Person		**1.44**	**0.04**	**35.87**	**<0.001*****
Experiment		0.14	0.08	1.74	0.49
Language × Person		**0.41**	**0.08**	**4.87**	**<0.001*****
Language × Experiment		**−0.33**	**0.08**	**−3.97**	**0.001*****
Person × Experiment		−0.10	0.08	−1.31	0.81
Language × Person × Experiment		**0.85**	**0.15**	**5.61**	**<0.001*****
Random effects		*Variance*	*SD*	*Corr*	
Subject	Intercept	0.01	0.11		
	Experiment	0.23	0.48	0.44	
Item	Intercept	0.01	0.09		
	Language	3.09	1.76	0.33	

Note: Results of best-fitting logistic mixed effects model of the language switching rate in Experiment 1 and 2, using Trial type as the DV (Repeat trials were coded as 0, Switch trials were coded as 1). Fixed-effect predictors: Language (L1 −0.5 and L2 0.5), Trial type (Repeat −0.5 and Switch 0.5), Person sequence (Within-person −0.5 and Cross-person 0.5), Experiment (Experiment 0.1 −0.5 and Experiment 2 0.5). For each predictor, the estimate, standard error, *z* values and *p* values are given. Asterisks indicate a significant effect. Random effects by subjects: intercept, Experiment slope. Random effects by items: intercept, Language slope.

frequency across Experiments 1 and 2. The main effect of Person sequence revealed that the switching rate in the Cross-person condition ($M = 48$, $SD = 5$) was higher than in the Within-person condition ($M = 21$, $SD = 11$), in line with the individual results from the two experiments. Of main interest was the interaction between Person sequence × Experiment, which would suggest that the influence of Person sequence on switching rate differed between the two experiments. This interaction was not significant, suggesting that the overall influence of Cross-person trials on switching frequency was similar for the two Experiments. The three-way interaction between Language × Person × Experiment showed that the experiments did show differences between L1 and L2. This was entirely driven by differences in the Within-person condition. Further analyses showed that the L1 switch rate in Experiment 2 ($M = 38$, $SD = 23$) was larger than that in Experiment 1 ($M = 22$, $SD = 13$) in the Within-person condition ($\beta = -0.56$, $SE = 0.11$, $z = -5.06$, $p < .001$), while there was no difference between the two experiments in the L2 Within-person condition (Experiment 1: $M = 23$, $SD = 14$, Experiment 2: $M = 25$, $SD = 20$; $\beta = 0.19$, $SE = 0.10$, $z = 1.86$, $p = .06$). The Cross-person condition, in contrast, showed no significant difference between Experiment 1 and Experiment 2 in either L1 or L2 (L1: Experiment 1: $M = 48$, $SD = 7$, Experiment 2: $M = 48$, $SD = 8$, $\beta = -0.04$, $SE = 0.10$, $z = -0.36$, $p = .72$; L2: Experiment 1: $M = 44$, $SD = 6$, Experiment 2: $M = 50$, $SD = 6$, $\beta = -0.13$, $SE = 0.09$, $z = -1.42$, $p = .156$).

The main difference between Experiment 1 and 2 was the amount of attention participants had to pay to the comprehension trials (i.e., Cross-person condition). Switching frequencies in this condition were similar in the two experiments, suggesting that participants were not more likely to follow the language used in comprehension trials when they were asked to respond to and focus more on those trials.

Language switching naming latencies results during production.

Table 7 and Fig. 6 shows the results from the analysis on naming latencies during production trials. The main effect of Language was significant, such that L1 trials showed longer naming latencies ($M = 924$ ms, $SD = 156$ ms) than L2 trials ($M = 883$ ms, $SD = 143$ ms). The main effect of Trial type was significant with longer latencies on Switch trials ($M = 917$ ms, $SD = 153$ ms) than on Repeat trials ($M = 889$ ms, $SD = 147$ ms). There was a significant interaction between Trial type × Person sequence, revealing that naming latencies on Switch trials ($M = 935$ ms, $SD = 74$ ms) were longer than those on Repeat trials ($M = 887$ ms, $SD = 71$ ms) in the Within-person condition ($\beta = -0.05$, $SE = 0.01$, $t = -8.23$, $p < .001$), but not in the Cross-person condition (Repeat: $M = 909$ ms, $SD = 72$ ms, Switch: $M = 916$ ms, $SD = 72$ ms; $\beta = -0.01$, $SE = 0.01$, $t = -1.72$, $p = .09$). As can be seen in Fig. 7, both L1 and L2 Within-person switch costs were larger than Cross-person switch costs (L1 within: $M = 46$ ms, $SD = 88$ ms versus L1 cross: $M = 20$ ms, $SD = 52$ ms; L2 within: $M = 17$ ms, $SD = 51$ ms versus L2 cross: $M = -8$ ms, $SD = 37$ ms). These findings were similar to Experiment 1 and indicated that language produced by others did not influence self-language.

Table 7
Mixed-effects model language switching for naming latencies in Experiment 2.

Predictor		*β*	*SE*	Contrast	
				t	*p*
Fixed effects					
Intercept		6.80	0.01	468.33	<0.001***
Language		**−0.03**	**0.01**	**−7.18**	**<0.001*****
Trial type		**0.03**	**0.01**	**6.71**	**<0.001*****
Person		0.01	0.01	0.14	>0.99
Language × Trial type		−0.01	0.01	−0.52	>0.99
Language × Person		−0.01	0.01	−0.04	>0.99
Trial type × Person		**−0.04**	**0.01**	**−5.76**	**<0.001*****
Language × Trial type × Person		0.01	0.02	0.51	>0.99
Random effects		*Variance*	*SD*	*Corr*	
Subject	Intercept	0.01	0.07		
	Language	0.01	0.02	0.03	
Item	Intercept	0.01	0.05		

Note: Results of best-fitting mixed effects model of the voluntary naming latency analysis, using log naming latencies as the DV. Fixed-effect predictors: Language (L1 −0.5 and L2 0.5), Trial type (Repeat −0.5 and Switch 0.5), Person sequence (Within-person −0.5 and Cross-person 0.5). For each predictor, the estimate, standard error, *t* values and *p* values are given. Asterisks indicate a significant effect. Random effects by subjects: intercept, Trial type slope. Random effects by items: intercept.

Similar to the switching rate analyses, we then compared naming latencies across Experiment 1 and Experiment 2. The new model added the fixed effect of Experiment to examine the differences between Experiment 1 and Experiment 2 (see Table 8). The main effect of Language showed that naming latencies in L1 ($M = 843$ ms, $SD = 180$ ms) were slower than in L2 ($M = 822$ ms, $SD = 155$ ms). The main effect of Trial type showed that naming latencies in Repeat trials ($M = 816$ ms, $SD = 162$ ms) were faster than Switch trials ($M = 848$ ms, $SD = 171$ ms). The main effect of Experiment revealed that naming latencies in Experiment 2 ($M = 899$ ms, $SD = 150$ ms) were longer overall than in Experiment 1 ($M = 756$ ms, $SD = 150$ ms), potentially because participants had to complete an extra task in Experiment 2. There was a significant interaction between Language × Trial type, reflecting larger switch costs to L1 than L2. In line with the individual experiments, the interaction between Trial type × Person sequence showed that switch costs were only observed in the Within-Person but not in the Cross-Person condition. The interaction between Person sequence × Experiment and between Trial type × Person sequence × Experiment showed that the effect of Person sequence on Trial type differed between the Experiments. This was driven by the Within-person condition, which showed a larger switch cost in Experiment 1 ($M = 74$ ms, $SD = 51$ ms) than in Experiment 2 ($M = 57$ ms, $SD = 56$ ms; $\beta = -0.05$, $SE = 0.01$, $t = -3.71$, $p = .001$). However, there was no significant switch cost difference between the Experiments in the Cross-person condition (Experiment 1: $M = -1$ ms, $SD = 21$ ms; Experiment 2: $M = 5$ ms, $SD = 19$ ms; $\beta = 0.01$, $SE = 0.01$, $t = 0.52$, $p > .99$). The main difference between Experiment 1 and 2 concerned the Cross-person condition (i.e., the comprehension trials). These analyses suggest that the inclusion of a judgement task did not modulate the effect of comprehension trials on production switch costs.

3.3. Discussion

Experiment 2, similar to Experiment 1, focused on voluntary language switching after language produced by the participants themselves versus after listening to language produced by others. We added a judgement task after each comprehension trial to make sure participants paid attention to those trials. Accuracy in the judgement task was high, confirming that participants paid attention to the comprehension trials. The results were similar to Experiment 1. Participants were more likely to repeat the language they just used in the Within-person condition than they were to repeat the language they just heard in the Cross-person condition. Furthermore, only the Within-person condition showed a switch cost. Switching languages from a comprehension to a production trial was not associated with a switch cost. This replication confirms that language produced by others has a smaller impact on language choice and language switching than language speakers produced themselves. While there were some differences between the experiments, these were mainly related to the Within-Person trials (which did not differ between experiments). The (absence of an) influence of comprehension trials on production trials was similar for the two experiments. This further confirms the findings of Experiment 1 and suggests that even when participants have to pay close attention to language produced by others, it has little effect on language switch costs during production.

Considering that previous research has suggested that voluntary and cued language switching might apply different amounts and types of language control (e.g., Green & Abutalebi, 2013), in the next Experiment, we assessed whether the observed pattern is unique to voluntary language switching or also observed in cued language switching.

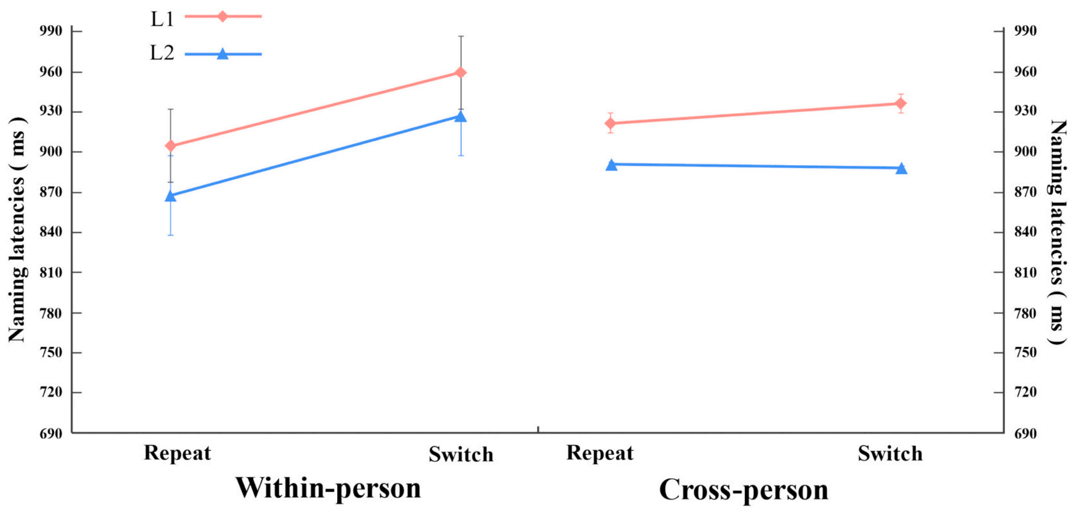

Fig. 6. Naming latencies in the voluntary language switching task (Experiment 2), using the original reaction times. Left and right panels show the mean naming latencies of Trial type (repeat and switch) by Language (L1, L2) in the within- and cross-person condition, respectively. Error bars for naming latencies show standard errors of naming latencies across subjects calculated separately for each level.

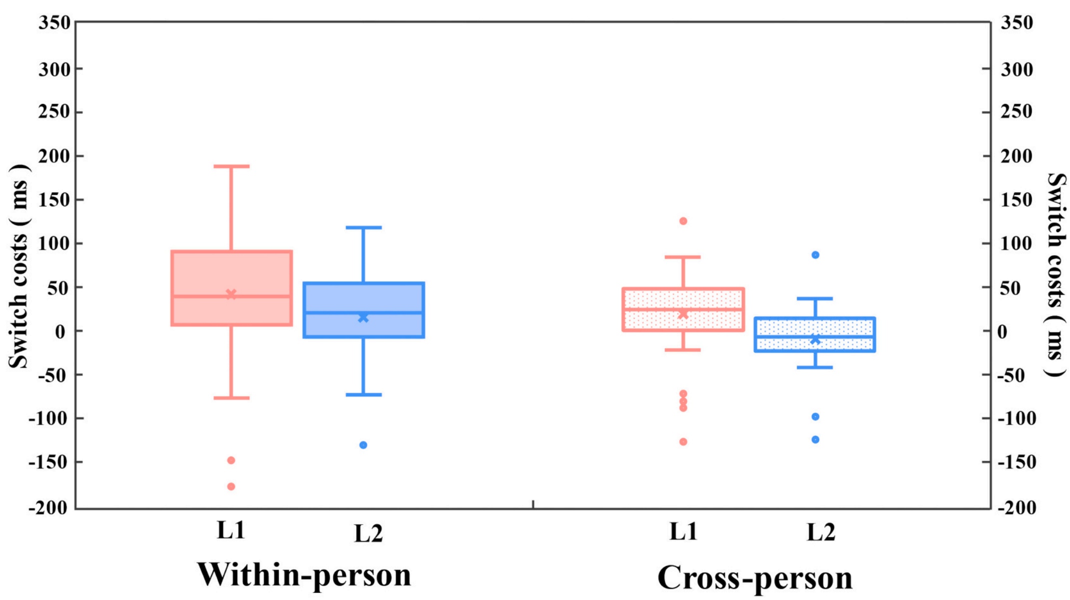

Fig. 7. Language switch costs in the Within- and Cross-person conditions. The boxes for switch costs are the upper and lower quartiles, the bars represent upper and lower edges, and the lines in the boxes show medians, the crosses represent the mean, the dots show outliers.

4. Experiment 3: cued language switching

4.1. Methods

4.1.1. Participants

In Experiment 3, 32 healthy volunteers from Liaoning Normal University participated. None of these participants had taken part in Experiment 1 or 2. All of them were right handed with normal or corrected-to-normal vision and no history of neurological or psychological impairments or receiving treatment with any psychoactive medication. Five participants were eliminated from the analysis due to too low accuracy. The final sample of participants was 27 (9 male) whose average age is 22 ± 2. All participants signed written informed consent. The research protocol was approved by the Institutional Review Board at the School of Psychology, Liaoning Normal University. The language acquisition pattern of the participants was comparable to Experiment 1, and the detailed information about them can be found in Table 1. Paired sample *t*-tests revealed that the proficiency ratings were significantly higher for L1 than L2: listening, $t\ (26) = 11.30, p < .001$; speaking, $t\ (26) = 12.28, p < .001$; reading, $t\ (26) = 7.89, p < .001$; writing, $t\ (26) = 6.86, p < .001$. Participants in Experiment 3 were unbalanced bilinguals with weaker proficiency in L2 than in L1.

4.1.2. Materials

The same materials were used as in Experiment 1.

4.1.3. Procedure

In the cued picture naming task, participants were no longer free to choose the language they wanted to use but had to name the picture according to a cue (see Fig. 8). The cue indicated the assigned task — listening or speaking — and the naming language — L1 or L2. The square surrounding the pictures indicated which naming language had to be used (red represented Chinese and blue represented English). In contrast, when participants saw a white circle around a triangle like in

Table 8
Mixed-effects model of naming latencies for Experiment 1 vs. 2.

Predictor		β	SE	Contrast	
				t	p
Fixed effects					
Intercept		6.71	0.01	569.76	<0.001***
Language		**−0.02**	**0.01**	**−3.84**	**0.002****
Trial type		**0.04**	**0.01**	**10.02**	**<0.001*****
Person		−0.01	0.01	−1.45	0.91
Experiment		**0.18**	**0.02**	**9.25**	**<0.001*****
Language × Trial type		**−0.02**	**0.01**	**−3.64**	**0.004****
Language × Person		0.01	0.01	1.73	0.73
Trial type × Person		**−0.07**	**0.01**	**−12.74**	**<0.001*****
Language × Experiment		−0.02	0.01	−2.61	0.13
Trial type × Experiment		−0.01	0.01	−1.99	0.52
Person × Experiment		**0.03**	**0.01**	**3.44**	**0.009****
Language × Trial type × Person		0.01	0.01	0.75	>0.99
Language × Trial type × Experiment		0.02	0.01	1.57	0.85
Language × Person × Experiment		**−0.04**	**0.01**	**−3.20**	**0.022***
Trial type × Person × Experiment		**0.05**	**0.01**	**4.21**	**<0.001*****
Language × Trial type × Person × Experiment		−0.01	0.02	−0.32	>0.99
Random effects		*Variance*	*SD*	*Corr*	
Subject	Intercept	0.01	0.07		
	Trial type	0.01	0.02	0.13	
	Person	0.01	0.03	0.07	−0.71
Item	Intercept	0.01	0.05		
	Language	0.01	0.03	−0.40	
	Person	0.01	0.05	−0.10	0.29

Note: Results of best-fitting mixed effects model of voluntary naming lantency between Experiment 1 and 2, using log naming latencies as DV. Fixed-effect predictors: Language (L1 −0.5 and L2 0.5), Trial type (Repeat −0.5 and Switch 0.5), Person sequence (Within-person −0.5 and Cross-person 0.5), Experiment (Experiment 1 −0.5, Experiment 2 0.5). For each predictor, the estimate, standard error, t values and *p* values are given. Asterisks indicate a significant effect. Random effects by subjects: intercept, Trial type slope, Person sequence slope. Random effects by items: intercept, Language slope, Person sequence slope.

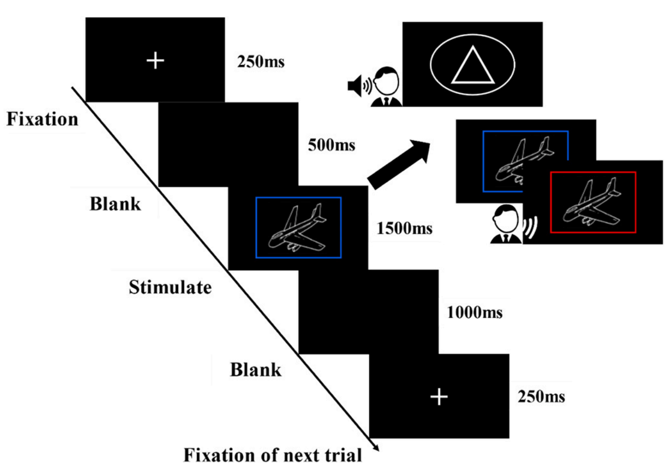

Fig. 8. Illustration of the cued language switching procedure. Participants had to listen carefully when they saw the white circle around a triangle (Cross-person); they had to name the picture when they saw the square with different colors (Within-person). Participants sometimes had to use the same language (L1 or L2) continuously (Repeat), or to switch from one language to another (Switch).

Experiment 1, they had to listen carefully. There were 16 conditions for language production and language comprehension, with an average of 36 trials for each condition. We only analyzed the 8 conditions belonging to production trials. All conditions were presented in a pseudo-random order so that participants did not know whether the next trial was going to be production or comprehension and L1 or L2. We collected a total of 288 production trials for each participant. The details of the remaining experimental procedures were the same as those of Experiment 1.

4.1.4. Analysis

Error responses were recorded as follows: A) no response; B) wrong language (naming did not match the cue); C) correct language but wrong word (naming did not match the picture); D) using two languages in a trial; E) a trial after an error response. Error responses were regarded as wrong trials and removed. Further, data from the first two trials of each block and the naming latencies beyond $M \pm 3SD$ were also excluded. This excluded 10% of the total data, on average leaving 260 trials per participant. The average accuracy of the simple judgement questions at the end of each block was 50%. The specific analysis and processing steps were the same as in Experiment 1. All models converged and all fixed effects were two-level categorical predictors and coded as −0.5 and 0.5. The reported *p* values were adjusted with Bonferroni correction.

4.2. Results

Average accuracy was high in both L1 and L2 across Repeat and Switch trials in Within- and Cross-person conditions, respectively (L1 Repeat trials in the Within-person condition: 93%; L1 Switch trials in the Within-person condition: 91%; L2 Repeat trials in the Within-person condition: 95%; L2 Switch trials in the Within-person condition: 94%; L1 Repeat trials in the Cross-person condition: 96%; L1 Switch trials in the Cross-person condition: 95%; L2 Repeat trials in the Cross-person condition: 96%; L2 Switch trials in the Cross-person condition: 97%). As accuracy was close to ceiling and not of specific interest for the current study, it was not analyzed further.

4.2.1. Language switching naming latencies results

Table 9 and Fig. 9 show the cued language switching results. There was a main effect of Language, indicating that L1 naming ($M = 882$ ms, $SD = 246$ ms) was slower than L2 ($M = 821$ ms, $SD = 219$ ms). The main effect of Trial type showed longer naming latencies on Switch trials ($M = 860$ ms, $SD = 236$ ms) relative to those on Repeat trials ($M = 842$ ms, $SD = 232$ ms). The main effect of Person sequence revealed longer naming latencies in Cross-person trials ($M = 867$ ms, $SD = 236$ ms)

Table 9
Mixed-effects model of cued language switching for naming latencies in Experiment 3.

Predictor		β	SE	Contrast	
				t	p
Fixed effects					
Intercept		6.71	0.03	197.94	<0.001***
Language		**−0.07**	**0.01**	**−6.00**	**<0.001*****
Trial type		**0.03**	**0.01**	**4.75**	**<0.001*****
Person		**0.04**	**0.01**	**5.04**	**<0.001*****
Language × Trial type		−0.01	0.01	−0.28	>0.99
Language × Person		0.01	0.01	0.33	>0.99
Trial type × Person		**−0.06**	**0.01**	**−5.07**	**<0.001*****
Language × Trial type × Person		0.02	0.02	0.86	0.98
Random effect		*Variance*	*SD*	*Corr*	
Item	Intercept	0.002	0.04		
	Language	0.001	0.03	−0.36	
	Person	0.002	0.04	0.01	0.59
Subject	Intercept	0.030	0.17		
	Language	0.002	0.05	−0.43	

Note: Results of best-fitting mixed effects model of the analysis on cued naming latencies, using log naming latencies as the DV. Fixed-effect predictors: Language (L1 −0.5 and L2 0.5), Trial type (Repeat −0.5 and Switch 0.5), Person sequence (Within-person −0.5 and Cross-person 0.5). For each predictor, the estimate, standard error, *t* values and *p* values are given. Asterisks indicate a significant effect. Random effects by subjects: intercept, Language slope. Random effects by items: intercept, Language slope, Person sequence slope.

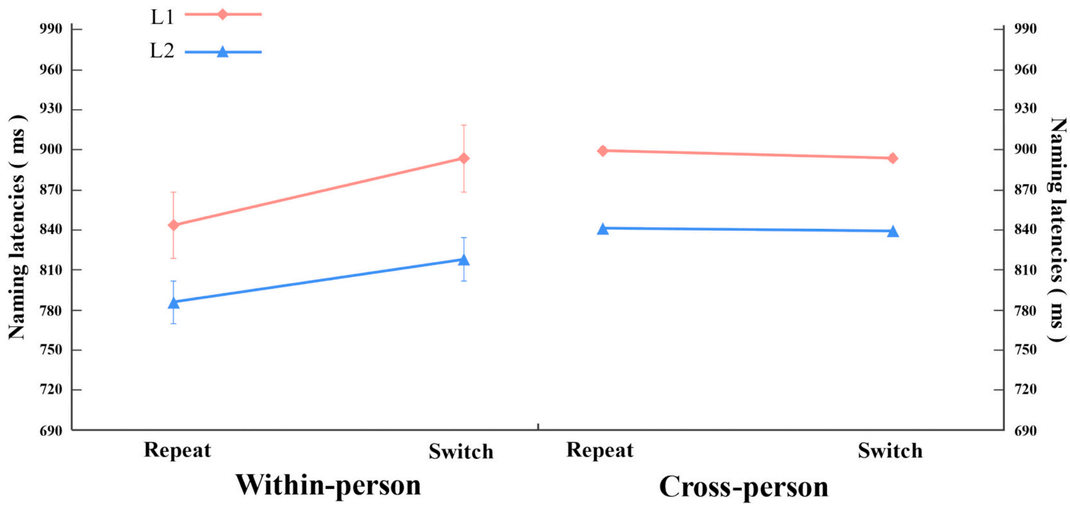

Fig. 9. Naming latencies of cued language switching, using the original reaction times. Left and right panels showed the mean naming latencies of Trial type (repeat and switch) across Language (L1, L2) in the Within- and Cross-person condition, respectively. Error bars for naming latencies show standard errors of naming latencies across subjects calculated separately for each level. Note that error bars were too small to be seen for L2.

relative to those in Within-person trials (M = 834 ms, SD = 233 ms). There was no interaction between Language and Trial type, reflecting similar switch costs in L1 and L2.

The two-way interaction between Trial type × Person sequence showed longer naming latencies in Switch Within-person trials (M = 855 ms, SD = 235 ms) than in Repeat Within-person trials (M = 814 ms, SD = 228 ms) ($\beta = -0.06$, SE = 0.01, $t = -6.87$, $p < .001$). In contrast, there was no switch cost in the Cross-person trials ($\beta = 0.01$, SE = 0.01, $t = 0.25$, $p = .81$). These findings are consistent with Experiments 1 and 2. These findings furthermore did not interact with Language. In the L1, the switch cost was larger in the Within-person condition (M = 53 ms, SD = 70 ms) than in the Cross-person condition ($M = -5$ ms, SD = 41 ms). The same pattern was found in the L2 (Within-person: M = 32 ms, SD = 38 ms, Cross-person: M = 0 ms, SD = 46 ms; see Fig. 10). These findings further suggest that cross-language interference is mainly driven by the self-language system, like in the voluntary switching experiments.

To see whether there are any differences between the cued and voluntary experiments, we conducted an analysis directly comparing Experiments 1 and 3. We compared these two experiments because they did not include animacy judgements after each comprehension trial and as such were more similar. The new model added the fixed effect of Experiment and the results are shown in Table 10. The significant main effect of Language showed that L1 naming latencies (M = 819 ms, SD = 215 ms) were slower than L2 (M = 782 ms, SD = 182 ms). In line with the individual experiments, there was a main effect of Trial type (indicating a switch cost, Switch trials: M = 823 ms, SD = 210 ms, Repeat trials: M = 784 ms, SD = 190 ms) as well as a two-way interaction between Trial type × Person sequence reflecting significant switch costs in the Within-person condition ($\beta = -0.07$, SE = 0.01, $t = -13.45$, $p < .001$) but not in the Cross-person condition ($\beta = 0.01$, SE = 0.01, $t = 0.92$, $p = .36$). Of main importance for this analysis across experiments is the finding that this interaction between Trial type × Person sequence did not interact with Experiment. In other words, the difference in switch costs between the Within- and Cross-Person condition was similar for cued and voluntary switching tasks. This confirms that during both

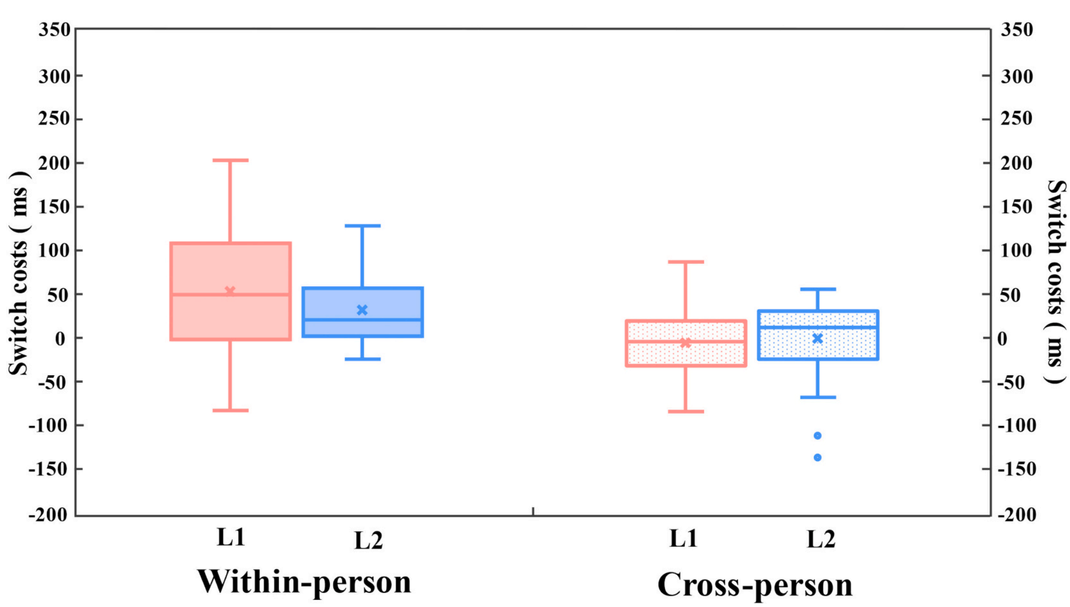

Fig. 10. Language switch costs in within- and cross-person conditions. The boxes for switch costs are the upper and lower quartiles, the bars represent upper and lower edges, and the lines in the boxes show medians, the crosses represent the mean, the dots show outliers.

Table 10
Mixed-effects model of naming latencies for Experiment 1 vs. 3.

Predictor		*β*	SE	Contrast	
				t	*p*
Fixed effects					
Intercept		6.67	0.02	357.54	<0.001***
Language		**−0.04**	**0.01**	**−4.53**	**<0.001*** **
Trial type		**0.03**	**0.01**	**9.35**	**<0.001*** **
Person		0.01	0.01	1.24	0.98
Experiment		0.08	0.03	2.35	0.26
Language × Trial type		−0.02	0.01	−2.31	0.28
Language × Person		0.01	0.01	1.98	0.54
Trial type × Person		**−0.08**	**0.01**	**−10.61**	**<0.001*** **
Language × Experiment		**−0.06**	**0.01**	**−3.91**	**0.001** **
Trial type × Experiment		−0.01	0.01	−1.86	0.63
Person × Experiment		**0.07**	**0.01**	**9.89**	**<0.001*** **
Language × Trial type × Person		0.02	0.01	1.47	0.91
Language × Trial type × Experiment		0.02	0.01	1.41	0.93
Language × Person × Experiment		−0.02	0.01	−1.76	0.72
Trial type × Person × Experiment		0.02	0.01	1.72	0.75
Language × Trial type × Person × Experiment		0.03	0.03	1.12	>0.99
Random effects		*Variance*	*SD*	*Corr*	
Subject	Intercept	0.017	0.13		
	Language	0.002	0.05	−0.33	
Item	Intercept	0.002	0.05		
	Language	0.001	0.03	−0.39	
	Person	0.001	0.04	−0.10	0.27

Note: Results of best-fitting mixed effects model of naming lantency between Experiment 1 and 3, using log naming latencies as DV. Fixed-effect predictors: Language (L1 −0.5 and L2 0.5), Trial type (Repeat −0.5 and Switch 0.5), Person sequence (Within-person −0.5 and Cross-person 0.5), Experiment (Experiment 1 −0.5, Experiment 3 0.5). For each predictor, the estimate, standard error, t values and p values are given. Asterisks indicate a significant effect. Random effects by subjects: intercept, Language slope. Random effects by items: intercept, Language slope, Person sequence slope.

cued and voluntary language switching preceding production trials have a greater influence on production switch costs than preceding comprehension trials.

The interaction between Language × Experiment is in line with Experiment 1 (voluntary) showing no overall naming latencies difference between L1 and L2 while Experiment 3 (cued) showed slower L1 than L2 responses. The interaction between Person sequence × Experiment reflects the finding that in Experiment 3 overall responses were slower in the Cross-Person condition while in Experiment 1 they were somewhat slower in the Within-Person condition.

4.3. Discussion

Similar to Experiments 1 and 2, Experiment 3 showed significant switch costs in the Within-person condition but not in the Cross-person condition. Comparisons between Experiments 1 and 3 showed that this pattern is indeed similar for both cued and voluntary switching tasks. Further comparisons by language showed that switch costs were larger in the Within-person than in the Cross-person condition in both L1 and L2. These findings suggest that in cued tasks too, cross-language interference might mainly stem from own language production while language produced by others has less of an influence on language control.

In contrast to Experiment 1, a main effect of Person was observed reflecting longer naming latencies in the Cross-person than the Within-person condition. One possible explanation is that main effects of Person (with slower responses when going from comprehension to production) appear when the tasks are more demanding. In the cued task in Experiment 3, there was a larger variety of cues than in the voluntary tasks. It is possible that these different types of cues introduced a greater need for task monitoring when switching between comprehension and production tasks. These main effects of Person, however, appear to reflect task switches rather than effects on language control given that language switch costs were not observed when switching between comprehension and production trials.

5. General discussion

The current study employed cued and voluntary language switching tasks to investigate whether and how language information stemming from other speakers influences self-language production processes when going from language perception to language action. The two voluntary switching experiments showed that, in terms of language choice, bilinguals are more likely to follow their own previously used language than they are to follow the language previously used by another speaker. Furthermore, in terms of naming latencies, larger switch costs in the within-person condition than in the cross-person condition were found during both cued and voluntary language switching, suggesting that cross-language interference primarily stems from the self-language system rather than from language produced by others.

5.1. Cross-language interference mostly comes from self -language production behaviour

According to the Interactive Alignment Model (Garrod & Pickering, 2009; Pickering & Garrod, 2004), others' speech should prime bilinguals to use the same language to name in the subsequent trial. Indeed, Kootstra et al.'s (2010) study showed that language produced by an interlocutor affects one's own language production. Participants were found to align their word order choice and code-switching patterns with a confederate. Our findings show that participants are more likely to use the language they themselves just used than to use the language just used by the other person. This is in line with a corpus analysis showing that within-language priming is stronger than cross-language priming (Cacoullos & Travis, 2018) and other corpus analyses showing that the tendency to switch languages is influenced more strongly by self-priming than by priming from an interlocutor (Fricke & Kootstra, 2016).

In terms of processing costs, language-switch costs were observed within the self-production task but not when preceded by language produced by others. This is in contrast to other behavioral studies (e.g., Gambi & Hartsuiker, 2016; Peeters et al., 2014) showing increased production costs after listening to an interlocutor using another language. Those studies required the speaker to always produce words in the same language. In our study, the speaker had to use both languages interchangeably. It is possible that language switches produced by an interlocutor have a larger hindering effect when a speaker needs to stay in one specific language than when they are in a more bilingual switching mode as in our experiments. Differences between these studies and ours are unlikely to be related to task demands during the comprehension trials, given that cross-person switch costs were absent when comprehension trials required passive listening (similar to Gambi & Hartsuiker, 2016) and when participants completed a judgement task (similar to Peeters et al., 2014). Our findings are compatible with recent neuroimaging research suggesting different neural circuits for production and comprehension (e.g., Blanco-Elorrieta & Pylkkänen, 2016). Our results suggest that speech produced by others creates minimal cross-language interference.

There are several reasons why comprehension might not interfere with language production. First, different mechanisms might be involved in comprehension versus production. The Bilingual Interactive-Activation model from a developmental perspective (BIA-d) (Grainger et al., 2010) argues that the switch costs in language comprehension rely on exogenous control which first activates the corresponding language node after hearing a word, and then inhibits the other language's lexical processes. Language switching during production is said to employ endogenous control which first activates the target language node and then accesses the lexical items. Comprehension governed by exogenous control might be more influenced by bottom-up processes related to the stimuli, while production governed by endogenous control might be more controlled by the top-down self-language system.

Another interpretation is that the difference between production and comprehension is not qualitative but rather quantitative. Comprehension and production might differ in terms of the *amount* of language interference and the control that is needed. Production trials required the execution of a response, which might lead to more interference than the comprehension trials that either required no response at all or a nonverbal response. Self-priming might be the result of increased activation of a previously used structure/language facilitating retrieval of that structure/language (cf. Jacobs et al., 2019). Production trials might potentially have strengthened activation of the used language more strongly than comprehension trials. This interpretation is in line with Declerck et al.'s (2019) study reporting switch costs during task switching, modality switching, and language production, but not during comprehension, potentially because language competition is reduced during comprehension.

Furthermore, this interpretation is compatible with previous work suggesting that preparing a response without executing it does not lead to language-switch costs in the next trial (Philipp & Koch, 2016). The results from Experiment 2, however, suggest that the participants did not simply view the comprehension trials as irrelevant or no-go trials. We also observed a switch effect (cost in L2 and benefit in L1) during comprehension trials, suggesting that the absence of the production switch cost after comprehension trials was not due to absent comprehension switch costs or lack of co-activation of the "other" language and language interference during comprehension.

A third explanation considers that (language) switch costs in the cross-person condition involved two types of task-set switches, namely language switching (repeat vs. switch) and modality switching (within vs. cross). Previous research on task switching has shown that when a task incorporates switches between two types of components, response times are most strongly reduced when both components are repeated. Repeating one component while switching the other component might only lead to a small or no naming latencies reduction compared to switching both components (Kleinsorge & Heuer, 1999; Philipp & Koch, 2010; Seibold et al., 2019). In our study, a repetition of both modality and language was indeed associated with the fastest responses. The above-mentioned task switching studies suggest that individual task-set components are integrated into a single representation. This binding of different task-set components (cf. the idea of task-specific stimulus-response bindings by Allport & Wylie, 2000; Frings et al., 2020; Hommel, 2004; Henson et al., 2014) requires a repetition of all task-set components to speed up responses. Following this interpretation, participants in our study might have switched between four task representations: language repetition/within modality; language repetition/cross modality; language switch/within modality; language switch/cross modality. In Experiments 2 and 3, naming latencies were shortest in the integrated task-set condition that repeated both components (i.e., language repetition and within-modality). This is in line with the interpretation that responses are facilitated by repetition of both modalities. However, Experiment 1 showed a different pattern. In this experiment, naming latencies were similar for the language repetition/within modality (no switches), the language repetition/cross modality (one switch), and language switch/cross modality (two switches) conditions. The larger within-condition cost was driven by slower language switch/within modality (one switch) condition. Thus, an integrated task-set without any component switches facilitating responses could potentially play a role when task demands are higher (i.e., in cued switching requiring responses to more complex cues and when comprehension trials require a response) but does not explain the overall result pattern across experiments.

5.2. Voluntary versus cued language switching

Overall, the cued and voluntary tasks showed similar result patterns. According to the Adaptive Control Hypothesis (Green & Abutalebi, 2013), cued language switching resembles the dual-language context, which needs more top-down control (e.g., conflict monitoring, inhibition), while voluntary language switching resembles the 'dense code-switching' environment, which might at least partly be driven by bottom-up control (lexical access). Our study showed similar patterns for the cued and voluntary switching tasks, with no significant language switch cost when going from comprehension to production. In all three experiments (both voluntary and cued), however, a significant language switch cost was observed. While some voluntary switching studies have found no cost or a smaller cost than in cued switching (e.g., Blanco-Elorrieta & Pylkkänen, 2017; Kleinman & Gollan, 2016), our findings are in line with other studies that show voluntary switch costs (e.g., de Bruin et al., 2018; Gollan & Ferreira, 2009; Gollan, Schotter, et al., 2014). The presence of these costs could suggest that even when bilinguals switch freely, reactive control might be needed to control interference coming from the other language. In addition, voluntary language choice and switching might not be purely driven by bottom-up processes such as priming or lexical access but are also modulated by top-down factors such as the speaker's intention to use a specific language (Green, 2018).

In the first voluntary experiment, switch costs were larger when switching to L1 than when switching to L2. Previous voluntary-switching studies have either shown no costs or similar costs for L1 and L2 (de Bruin et al., 2018; Gollan & Ferreira, 2009; Gollan, Schotter, et al., 2014; Gross & Kaushanskaya, 2015; Jevtović et al., 2020; Kleinman & Gollan, 2016). If voluntary language choice is driven by lexical access (i.e., the word that comes to mind fastest is used regardless of the language), similar costs should be observed for both languages. In this study, we show a different pattern, with larger costs when switching to L1. In cued tasks, this pattern is often interpreted in light of the Inhibitory Control Hypothesis (Green, 1998). If the L1 is inhibited more strongly when using the L2, more time might be needed to release inhibition when having to switch back to the L1. In addition, Experiment 2 (voluntary) and 3 (cued) showed faster L2 than L1 responses. In cued tasks, this reversed dominance effect has been associated with global L1 inhibition to allow the bilingual to use both languages interchangeably (e.g., Kleinman & Gollan, 2018). While the (a)symmetry of switch costs and the reversed dominance effects were not found in both voluntary experiments and should thus be interpreted cautiously, these findings do suggest that bilinguals used some form of top-down control during both voluntary and cued switching.

6. Conclusion

While many studies have investigated self-language production, relatively little work has been done on the influence of language produced by others on self-language production, even though the latter would help to better understand language communication in a bilingual context. The current study showed that unbalanced bilinguals are more likely to repeat the language they just produced themselves than to repeat the language just produced by others. Language switch costs for both languages were larger when the bilingual had just produced the other language themselves as compared to when they had just heard the other language. These findings suggest that cross-language interference mainly stems from the self-language during both cued and voluntary language switching, which does not confirm the Interactive Alignment Model.

Conflict of interest

The authors declared that they have no conflicts of interest to this work.

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