Cognitive Switching Advantages of Interpreters Interpreting is a highly complex cognitive activity, requiring interpreters to perform rapid and accurate switching between source and target languages. This continuous cognitive switching training may confer significant advantages in cognitive contr…

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Abstract

Interpreting may be conceptualized as an intensified bilingual switching activity. Compared with general bilinguals, interpreters demonstrate advantages in both rule-based switching and task-based switching, although controversies regarding task-based switching advantages persist concerning the relative contributions of local switching versus global monitoring. Preliminary investigations suggest that interpreter training initially engenders local switching advantages (switching costs in univalent tasks), subsequently conferring global monitoring advantages (mixing costs in bivalent tasks). The high-intensity language switching and specialized language control characteristics inherent to interpreting may constitute critical factors influencing interpreters'cognitive switching advantages. These findings carry implications for bilingual advantages and related research domains.

Full Text

Interpreter Advantages in Switching Ability

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Abstract: Interpreting can be regarded as an intensive bilingual switching activity. Compared with general bilinguals, interpreters have demonstrated advantages in both rule-based switching and task-based switching. However, controversy exists regarding whether interpreter advantages in task-based switching originate from local switching or global monitoring. Preliminary evidence suggests that interpreting training first brings interpreters an advantage in local switching (indexed by switch cost in univalent tasks), and subsequently may bring an advantage in global monitoring (indexed by mixing cost in bivalent tasks). The high-intensity language switching involved in interpreting and its special language control characteristics may be factors influencing interpreters' cognitive switching advantages. These results have implications for research on bilingual advantages and other related topics.

Keywords: cognitive switching ability, interpreter advantage in switching, rule-based switch, task-based switch, bilingual advantage
Classification Number: B842

How language experience influences individuals' cognitive control abilities has become a hot topic in academic research. Compared with monolingual experience, bilingual experience involves one crucial difference: experience in language switching. Research has found that language switching shares partially overlapping neural mechanisms with general task switching (e.g., de Baene et al., 2015; Weissberger et al., 2015; for reviews see Abutalebi & Green, 2016; He Wenguang & Chen Baoguo, 2011; Liu Huanhuan & Chen Baoguo, 2015; Sun Xun et al., 2017). Therefore, long-term language switching experience may enhance bilinguals' cognitive switching abilities. Researchers have conducted numerous empirical studies to test this hypothesis, yet results are mixed—some support it (e.g., Prior & Gollan, 2011; Prior & MacWhinney, 2010; Jiao Lu et al., 2016), while others do not (e.g., Paap & Greenberg, 2013; Paap & Sawi, 2014). This inconsistency may be related to the complexity of bilinguals' language communication contexts (Li & Dong, 2020). According to the Adaptive Control Hypothesis proposed by Green and Abutalebi (2013), different contexts require different language control mechanisms. To adapt to contextual control demands, bilinguals adjust their executive functions accordingly, resulting in differential impacts on executive functions. By extension, bilingual cognitive switching advantages may emerge only under certain language switching conditions.

In this context, interpreting—as a high-frequency, high-intensity bilingual switching situation—warrants attention. First, since interpreters must switch back and forth between source and target languages under strong time pressure, they may need to recruit their cognitive switching abilities more than general bilinguals, making them more likely to develop cognitive switching advantages. Second, if interpreters can demonstrate cognitive switching advantages compared with general bilinguals, this would not only provide further evidence for the hypothesis that bilingual experience enhances switching ability but also help answer questions about the conditions under which such advantages emerge. To date, empirical data have shown that switching ability is related to interpreting proficiency (MacNamara et al., 2011; Timarová et al., 2014), providing support for exploring interpreter cognitive switching advantages. Moreover, compared with research on bilingual cognitive switching advantages, findings on interpreter advantages have been more consistent (for reviews see Dong & Zhong, 2019; García, 2014; García et al., 2019).

This paper first defines cognitive switching ability, then reviews findings on interpreter cognitive switching advantages, and finally discusses factors influencing these advantages, aiming to provide insights for related research fields.

2 Cognitive Switching Ability and Its Measurement

Cognitive switching ability refers to the capacity to shift between different cognitive tasks or mental states according to situational changes (Diamond, 2013; Miyake & Friedman, 2012). In the literature, it is also termed switching ability, mental set shifting, or cognitive/mental flexibility. As the definition indicates, cognitive switching can occur at different levels, including both abstract thinking and concrete task performance. Correspondingly, experimental paradigms for measuring switching ability fall into two categories. The first measures switching caused by changes in task rules, which can be called rule-based switch, or simply "rule switching." The second measures switching induced by changes in stimulus features or response keys, which can be called task-based switch, or simply "task switching." Below we introduce representative measurement tools for these two paradigms.

The representative tool for the "rule switching" paradigm is the Wisconsin Card Sorting Test (WCST). This task typically consists of 64 or 128 response cards and 4 stimulus cards. The 4 stimulus cards are displayed in parallel on the computer screen throughout the test, with each stimulus card featuring geometric shapes that differ in color, shape, and number dimensions. During testing, participants must classify each newly presented response card to one of the stimulus cards without knowing the classification rule beforehand. Participants discover the rule through "correct" or "incorrect" feedback after each response. After several trials, the rule changes, and participants must adjust their classification strategy based on feedback. WCST includes numerous metrics, such as categories completed (reflecting overall performance) and various error-related indicators: total errors, perseverative errors, and perseverative errors according to the previous classification rule. The last metric specifically reflects the number of trials in which participants continue to apply the previous rule after receiving negative feedback. This indicator most typically reflects cognitive flexibility—the higher the value, the more difficulty participants have shifting their mindset to other rules, indicating poorer switching ability.

The most common "task switching" paradigm is the color-shape switching task. This task requires participants to judge either the color (e.g., "red" or "green") or shape (e.g., "circle" or "triangle") of graphic stimuli via key press. The entire task comprises single blocks and mixed blocks. In single blocks, participants perform only color judgments or only shape judgments, whereas in mixed blocks, participants decide whether to perform color or shape judgments based on provided cues. If the current trial' s judgment task matches the previous trial' s, it is a repeated trial; otherwise, it is a switch trial. Performing switch tasks incurs two types of cognitive costs. Switch cost refers to the difference in average reaction time or accuracy between switch trials and non-switch trials within mixed blocks, reflecting specific, transient control mechanisms during actual task switching (Braver et al., 2003; Logan & Bundesen, 2003). Mixing cost refers to the difference in average reaction time or accuracy between non-switch trials in mixed blocks and trials in single blocks, reflecting overall, sustained conflict monitoring capacity required to maintain activation of two task sets in a potential switching context (Braver et al., 2003; Koch et al., 2005).

3 Interpreter Cognitive Switching Ability and Its Advantages

Research indicates that cognitive switching ability both participates in interpreting processing and is influenced by interpreting experience (e.g., Dong & Li, 2020). However, substantial variation exists across studies. When discussing these differences, we emphasize analyzing the nature of switching ability in conjunction with interpreting characteristics (particularly interpreter development), while also considering impacts from different tasks and metrics. Because interpreting is an extremely complex and demanding task, the interactive relationship between cognitive switching ability and interpreting may vary across interpreters at different developmental stages, requiring corresponding adjustments to measurement methods. Following this logic, we propose worthwhile future research questions and possible solutions.

3.1 Cognitive Switching Ability in Interpreting Tasks

Currently, research on this topic consists mainly of exploratory studies. On one hand, evidence shows that interpreters' cognitive switching ability correlates with interpreting performance. MacNamara et al. (2011) found that switching ability could predict interpreting proficiency. They compared sign language-English simultaneous interpreting (SI) interpreters of different proficiency levels on the number-letter sequencing task (another tool for measuring task switching ability) and WCST, discovering that high-level interpreters performed significantly faster on the sequencing task and had marginally lower error rates on WCST. This suggests that interpreters with stronger switching ability likely demonstrate advantages in interpreting tasks. Timarová et al. (2014) correlated 28 professional interpreters' performance on the number-letter switching task with various metrics from an SI task (from L2 to L1), revealing that interpreters' switching ability negatively correlated with ear-voice span—the stronger the switching ability, the shorter the ear-voice span. On the other hand, some studies have failed to find correlations between switching ability and interpreting performance. MacNamara and Conway (2016) collected sign-to-English SI test scores from 34 SI trainees at different training time points and measured their switching ability using the number-letter sequencing task and WCST. They found no significant correlations between these switching metrics and SI test scores, nor could the metrics predict trainees' SI proficiency development during training.

These contradictory results suggest that interpreters' cognitive switching ability relates to specific processing components in SI (such as ear-voice span) but may not manifest in final test scores. From the perspective of interpreting characteristics, ear-voice span is almost unavoidable in SI because interpreters must first listen to and process a meaningful chunk of source language before producing target language. We speculate that if interpreters possess stronger cognitive switching ability, they may more easily convert source language information into target language expression, thereby shortening ear-voice span. Additionally, longer ear-voice span increases working memory load. Further speculation suggests that the correlation between ear-voice span and switching ability may essentially reflect mechanisms involving working memory processing in interpreting. Notably, although MacNamara and Conway (2016) found no correlation between switching ability and final SI test scores, interpreters' initial working memory capacity combined with initial SI test scores predicted up to 73% of variance in final SI test scores. This raises the question: might switching ability have an indirect association with interpreting test scores through working memory capacity? This warrants further verification (e.g., using structural equation modeling), with methods referenced in Dong Yanping et al. (2013).

3.2 Interpreter Cognitive Switching Advantages—Evidence from Rule Switching

The interpreter rule-switching advantage hypothesis has been replicated and verified in multiple studies. For example, Yudes et al. (2011) compared professional SI interpreters (n=16), general bilinguals (n=16), and monolinguals (n=16) on WCST performance, finding that professional SI interpreters made significantly fewer errors than the other two groups across total errors, perseverative errors, and perseverative errors according to the previous classification rule. Since SI interpreters had larger working memory capacity than the other groups, the researchers matched the three groups on working memory capacity and reanalyzed the data, which still revealed SI interpreters' advantages on the aforementioned WCST metrics. While the above demonstrates advantages in SI interpreters, other research has examined consecutive interpreting (CI) trainees. Dong and Xie (2014) included four groups: undergraduate CI trainees (n=46), graduate CI trainees (n=20), and their respective control groups (n=45 and n=43). Graduate CI trainees had received significantly more CI training than undergraduate trainees. The study found that both CI trainee groups significantly outperformed the two non-interpreting bilingual control groups on all four WCST metrics (categories completed, total errors, perseverative errors, and perseverative errors according to the previous rule). Moreover, after matching the two interpreting groups on L2 proficiency, graduate CI trainees also outperformed undergraduate CI trainees on some WCST metrics (categories completed, total errors, and perseverative errors according to the previous rule), suggesting that more interpreting training may further improve WCST performance.

Some studies have yielded slightly different results. Dong and Liu (2016) used WCST to test 44 CI trainees and 37 general bilingual students, finding that the interpreting group only significantly outperformed the control group on categories completed, with no group differences on other metrics. This may be related to the interpreting group having received only one semester of interpreting training. Additionally, Santilli et al. (2018) compared 17 professional SI interpreters with 17 general bilinguals on WCST, using only total errors and categories completed as metrics, and found no interpreter rule-switching advantage. Considering that WCST is a complex cognitive task that, while commonly used to measure cognitive switching ability, also involves inhibition, abstract thinking, and problem-solving abilities, interpreters' advantages on one or multiple WCST metrics may not be determined purely by cognitive switching ability but rather reflect the combined effect of multiple cognitive control functions at the current stage. Which WCST metrics better reflect interpreters' cognitive switching ability is discussed in Section 4.2.

All the above evidence comes from cross-sectional comparisons, whose inherent limitation is the inability to establish causality between interpreting experience and rule-switching advantages. Overcoming this limitation requires longitudinal tracking methods. MacNamara and Conway (2014) recruited 21 sign language-English SI trainees and measured their switching ability using WCST before and after approximately two years of interpreting training. Results showed that SI trainees' WCST accuracy significantly improved after training. However, this study lacked a control group for comparison, making it impossible to determine whether these changes in switching ability were truly caused by interpreting training or by other factors (such as practice effects from the WCST task).

In summary, despite some design limitations in longitudinal studies, evidence from both cross-sectional and longitudinal research mutually supports the conclusion that interpreting as a high-intensity language switching training can enhance interpreters' rule-switching ability.

3.3 Interpreter Cognitive Switching Advantages—Evidence from Task Switching

As described in Section 2, task switching involves two types of metrics: switch cost and mixing cost, which respectively reflect different control mechanisms in task switching—local switching ability (Braver et al., 2003; Logan & Bundesen, 2003) and global monitoring ability (Braver et al., 2003; Koch et al., 2005). Currently, interpreter task-switching advantages have been demonstrated on both metrics. However, some studies have only found local switching advantages

(Dong & Liu, 2016), while others have only found global monitoring advantages (Babcock & Vallesi, 2017; Becker et al., 2016). Additionally, some studies (Babcock et al., 2017; van de Putte et al., 2018) have found no advantage evidence. Given these complex results, it is necessary to identify factors causing this instability.

Recent research has conducted preliminary explorations. Zhao and Dong (2020) found that inconsistent results in the literature relate to design differences across studies. To clearly illustrate these differences, Table 1 lists the task types, participant characteristics, and advantage results from relevant literature.

Table 1 Manifestation of interpreter task-switching advantages across different color-shape switching tasks and participant conditions

Task Type	Study	Participant Type	Advantage Result
Univalent color-shape switching task	Dong & Liu (2016) Zhao & Dong (2020)	Consecutive interpreting students ($18 \leq n \leq 47$) Consecutive interpreting students ($18 \leq n \leq 37$)	Switching advantage a Switching advantage a
Bivalent color-shape switching task	Zhao & Dong (2020) Babcock et al., (2017) van de Putte et al., (2018) Becker et al., (2016) Babcock & Vallesi (2017)	Professional SI interpreters Professional SI interpreters General bilingual students General bilingual students General multilingual students General multilingual experts General multilingual experts	Monitoring advantage b Trend c Monitoring advantage b Monitoring advantage b

Notes: a. Switching advantage manifested in switch cost; b. Monitoring advantage manifested in mixing cost; c. Monitoring advantage trend refers to marginally significant between-group differences in mixing cost.

Two pieces of information can be obtained from this table. First, the manifestation of advantages on different metrics may relate to task valence design across studies. As shown in Table 1, Dong and Liu (2016) used a univalent color-shape switching task and found interpreter local switching advantages. This task features stimuli that are only associated with one of two attributes (color or shape) (e.g., a black-and-white line drawing of a triangle lacking color attributes), while response keys for color and shape judgments do not overlap. Babcock and Vallesi (2017) and Becker et al. (2016) used bivalent color-shape switching tasks and found interpreter global monitoring advantages. These tasks feature stimuli possessing both color and shape attributes (e.g., a colored triangle), with overlapping response keys for color and shape judgments. To verify the impact of task valence on measurement results, Zhao and Dong (2020) measured the same group of interpreters and controls using both univalent and bivalent tasks. They found that interpreters' switch cost was significantly smaller than controls' in the univalent task, while no significant group differences emerged in switch cost for the bivalent task, confirming that task valence indeed affects measurement outcomes.

Task valence effects can be explained through differences in task demands. Compared with univalent tasks, bivalent tasks impose higher demands because participants must overcome additional interference (e.g., ignoring color attributes when making shape judgments). Research indicates that this interference affects both switch and repeat trials, suggesting that the mechanism for overcoming interference is not specific to local switching processes but rather resembles a global control mechanism (Rubin & Meiran, 2005). Therefore, bivalent tasks may be more sensitive for detecting group differences in global monitoring ability. Conversely, since univalent tasks have lower global control requirements than bivalent tasks, they may be better suited for detecting group differences in local switching ability. However, some studies using bivalent tasks failed to find interpreter global monitoring advantages (Babcock et al., 2017; van de Putte et al., 2018), contradicting predictions based on task valence and suggesting that other factors may influence advantage outcomes.

Second, the instability of advantages (including null findings) may reflect dynamic development of advantages, whereby interpreter task-switching advantages may shift from local switching to global monitoring as interpreting training progresses. This hypothesis is based on participant differences across studies. Table 1 shows that interpreters in various studies represent three different training stages: (1) Initial stage–corresponding to CI trainees (Dong & Liu, 2016), who had received only one semester (approximately 4 months) of CI training before the experiment; (2) Intermediate stage–corresponding to SI trainees (Babcock et al., 2017; van de Putte et al., 2018), who had completed 9 months to 2 years of SI training; (3) Advanced stage–corresponding to professional SI interpreters (Babcock & Vallesi, 2017; Becker et al., 2016), who averaged over 13 years of SI work experience.

By classifying interpreting training stages, this hypothesis views interpreter global monitoring advantages as a product of later training stages, thereby explaining their relationship with local switching advantages. The underlying logic is as follows: First, research shows that language switching also produces switch costs and mixing costs, indicating that similar local switching and global monitoring mechanisms exist in language control processes (Declerck & Philipp, 2015), and both types of control consume cognitive resources. Interpreting is an extremely cognitively challenging task; from the perspective of language switching, interpreting places higher demands on both types of control, consuming more cognitive resources. However, interpreters' cognitive resources are limited. It is reasonable to assume that interpreters allocate different amounts of cognitive resources to these two types of control at different training stages.

What factors constrain cognitive resource allocation? An important factor is L2 proficiency. Based on participant descriptions in the aforementioned studies, interpreters at different training stages differ in L2 proficiency, primarily reflected in their matched control groups: control groups for CI and SI trainees were students with intermediate to advanced L2 proficiency, while control groups for professional SI interpreters were balanced bilinguals. We therefore infer the dynamic development principle of interpreter task-switching advantages as follows: In the initial interpreting stage, due to L2 proficiency limitations, interpreters may devote substantial effort to switching between two languages without capacity for overall interpreting process monitoring. Consequently, advantages first manifest at the local switching level. When transitioning to advanced stages, interpreters' L2 and L1 proficiency become more balanced, language switching becomes more automatic, and interpreters can allocate more resources to global interpreting control, thereby exercising and enhancing their global monitoring ability. In fact, Zhao and Dong (2020) partially verified this hypothesis. They divided recruited CI trainees (with 0.5 to 2 years of CI training) and controls into high and low L2 proficiency subgroups, finding that high L2 proficiency CI trainees showed not only local switching advantages (compared with matched controls) but also a trend toward global monitoring advantages (marginally significant between-group differences in mixing cost). This preliminary evidence demonstrates the influence of L2 proficiency on the development of interpreter task-switching advantages.

Beyond the behavioral-level interpreter task-switching advantages listed in Table 1, some studies have identified neural substrates for these behavioral advantages. As mentioned earlier, Becker et al. (2016), who found professional SI interpreter global monitoring advantages, conducted a magnetic resonance imaging study. Structural imaging data revealed that professional SI interpreters had greater gray matter (GM) volume than controls in the left frontal pole (frontal lobe, BA 10), and only the interpreter group showed marginally significant correlations between volume in this region and task-switching mixing cost. Graph-theoretical analysis of resting-state functional imaging data showed that interpreters had higher global efficiency and node degree in the frontal pole cluster (node degree in graph theory refers to the number of edges connected to a specific node). Furthermore, SI interpreters showed stronger functional connectivity between the frontal pole cluster and left middle temporal gyrus (MTG) and left inferior frontal gyrus (IFG). Based on these findings, the researchers inferred that SI interpreters' advantages in mixing cost may result from their more mature (left) frontal pole cortex (FPC), as previous research has linked this region to task switching and attention shifting, and the study found stronger connectivity between this region and IFG in SI interpreters.

In summary, preliminary evidence suggests that interpreting training may affect both interpreters' local switching and global monitoring abilities, but the manifestation of advantages is moderated by task valence and interpreting training stage. Related hypotheses have only received preliminary empirical exploration in Zhao and Dong (2020). Because that study lacked a group of professional SI interpreters performing both univalent and bivalent color-shape switching tasks for comparison, it remains uncertain whether interpreter task-switching advantages at advanced stages shift from local switching to global monitoring or whether both levels of advantages may emerge simultaneously. Future research urgently needs to supplement such data. Additionally, in Section 6 ("Conclusions and Prospects"), we discuss in greater detail the issues and methods for verifying the dynamic development hypothesis of interpreter task-switching advantages.

4 Factors Influencing Cognitive Switching Advantages

As evidence accumulates regarding interpreter cognitive switching advantages, relevant theoretical questions arise: What factors influence the emergence of these advantages? We may find possible answers in previous literature, which may also inspire general bilingual cognitive switching advantage research.

4.1 Influencing Factor 1: Language Switching Intensity

Compared with general bilingual switching experience, a prominent feature of interpreting is the need for frequent language switching within extremely short timeframes. Green and Abutalebi (2013) analyzed three contexts of bilingual conversational communication and linked them to various cognitive control functions, becoming one of the most cited articles in bilingual research. The second context, "dual-language context," seems particularly suitable for describing interpreting situations, characterized by bilinguals needing to use and frequently switch between two languages. The question is: Can merely frequent language switching produce cognitive switching advantages? Or for interpreters, what are the respective roles of frequent language switching (switching frequency) and language switching within extremely short timeframes (language switching intensity) in enhancing cognitive switching ability? We argue that language switching intensity plays a crucial role.

In fact, Dong and Liu (2016) explicitly proposed that training intensity may be an important factor influencing the emergence of cognitive control advantages in trainees. This study compared three groups of undergraduate participants on a univalent color-shape switching task, matching all possible influencing factors across groups while differing on only one dimension: a control group (n=37, general college English), a translation group (n=35, one semester of translation course), and an interpreting group (n=44, one semester of interpreting course). Results showed that only interpreting training produced additional advantages (i.e., additional reduction in switch cost) compared with the control group. This indicates that although both translation and interpreting require frequent language switching, translation training did not produce the same enhancement effect on switching ability as interpreting training. In other words, interpreting' s enhancement effect on individuals' switching ability stems not only from frequent language switching but more importantly from interpreting' s inherently high-intensity task demands. However, some studies have obtained results inconsistent with Dong and Liu (2016). Babcock et al. (2017) compared three groups of graduate students on a bivalent color-shape switching task: a control group (n=35, non-language majors, general multilingual group), a translation group (n=10, language majors, receiving translation and CI training), and an SI group (n=47, language majors, receiving translation, CI, and SI training). They found no advantages in the latter two groups compared with the control group, likely due to the complex backgrounds of participants.

van de Putte et al. (2018) used fMRI technology to compare two groups of participants before and after training on a bivalent color-shape switching task: students receiving 9 months of SI training and students receiving 9 months of translation training. Regarding behavioral metrics, no significant between-group differences emerged in either switch cost or mixing cost, and neither group' s pre-post changes on these metrics were significant. However, functional brain imaging results showed that students who received interpreting training activated the right angular gyrus more than those who only received translation training. The authors noted that the angular gyrus plays an important role in language switching and is related to cross-modal attentional control. Structural brain imaging connectivity analysis revealed that interpreting trainees showed enhanced connectivity in two brain networks compared with translation trainees. One network included eight regions covering the left supplementary motor area (SMA), right postcentral gyrus (PoCG), right superior frontal gyrus, right middle temporal pole (TPOmid), right amygdala, left inferior parietal gyrus (IPG), left superior parietal gyrus (SPG), and cerebellar vermis. Based on previous literature (Green & Abutalebi, 2013), the authors noted that SMA is responsible for initiating language production during language switching, while parietal regions (including superior and inferior parietal gyri) primarily maintain task representations. Therefore, although this study found no behavioral between-group differences, brain imaging data still supported the notion that interpreters have advantages over translators in switching ability.

4.2 Influencing Factor 2: Control Features of Language Tasks

Language switching intensity can explain the contrasting results between interpreting and translation training but is insufficient to account for two previously introduced findings: (1) the different result patterns between interpreter advantages in rule switching versus task switching, and (2) the transition from local switching advantages to global monitoring advantages in interpreter task switching.

Regarding the first point: Interpreter cognitive switching advantages are relatively stable at the rule-switching level but more controversial at the task-switching level. To explain this, we must further examine the control features of language switching in interpreting, which currently remains primarily at the theoretical level. According to the Attentional Control in Interpreting model recently proposed by Dong and Li (2020), language switching in interpreting is accomplished through the coordination of multiple executive functions, with working memory being an indispensable factor in both major control modules. Indeed, no one questions the heavy working memory load in interpreting activities, and interpreters have demonstrated stable advantages in working memory (see two recent meta-analyses: Mellinger & Hanson, 2019; Wen & Dong, 2019). This may provide an entry point for explaining differences between interpreters' rule-switching and task-switching advantages. WCST requires participants to remember multiple classification rules and decide whether to maintain or adjust rules based on feedback from previous trials. Therefore, WCST may depend more on working memory than color-shape tasks. Consequently, for interpreters who possess working memory advantages, their rule-switching advantages may be more stable than their task-switching advantages. Of course, this inference requires more empirical data for verification.

Regarding the second point: The transition from interpreter local switching advantages to global monitoring advantages may result from the fact that both switching and monitoring demands are higher in interpreting than in general bilingual switching. Under conditions of limited cognitive resources, interpreters prioritize resource allocation for simple switching between source and target languages before allocating resources to global interpreting monitoring. The dynamic development of advantages is actually a result of improved cognitive resource allocation efficiency, in which L2 proficiency improvement plays a certain role. Adapting to the high cognitive demands of interpreting tasks through cognitive resource allocation itself reflects the control features of language switching in interpreting and aligns with the Adaptive Control Hypothesis (Green & Abutalebi, 2013). Notably, controversies regarding local switching versus global monitoring advantages also exist in bilingual cognitive switching advantage research (for a review see Yang et al., 2016). Moreover, Jiao Lu et al. (2016) have proposed that certain developmental sequences may exist between these two types of advantages. The commonality of these issues makes exploration in interpreter advantage research more valuable for reference. The relationship between other control features of language switching in interpreting and interpreter cognitive switching advantages awaits further investigation.

A natural question arising from the control features of language switching in interpreting is how to select appropriate switching tasks and metrics to detect effects of these features. One principle is to consider tasks and metrics according to interpreting training stage. For instance, when measuring interpreter task-switching advantages, early-stage trainees may focus on local switching control, making switch cost in univalent tasks more suitable for detecting such control effects. Advanced interpreters with more capacity for global interpreting monitoring may show effects more easily captured by mixing cost in bivalent tasks. Although interpreter rule-switching advantages do not show obvious developmental patterns, WCST involves task purity issues, necessitating consideration of other developing abilities in interpreters. Furthermore, we speculate that total errors and categories completed are macro-level indicators reflecting participants' rule mastery, possibly more related to advanced cognitive abilities (e.g., abstract thinking). In contrast, subdividing error-type indicators may reveal that certain metrics reflecting trial-and-error processes after rule changes (e.g., perseverative errors) may be more related to cognitive switching ability, though manifestation of advantages in these metrics also requires support from other abilities.

5 Implications for Bilingual Cognitive Switching Advantage Research

By examining the characteristics of language switching in interpreting, we have preliminarily identified factors influencing interpreter cognitive switching advantages, which helps explain some controversies in previous empirical research. Similarly, when researchers encounter inconsistent results in bilingual cognitive switching advantage studies, analyzing the characteristics of bilingual switching experiences involved in each study may broaden perspectives. This implies:

First, specifying bilinguals' concrete language experiences is crucial. Currently, three main questionnaires are used in international bilingual research to survey bilinguals (LHQ, e.g., Li et al., 2019; LEAP-Q, Kaushanskaya et al., 2019; LSBQ, Anderson et al., 2018), but none include questions about translation/interpreting training or work experience. Additionally, Xie and Dong (2017) found that public speaking experience in either L1 or L2 enhanced cognitive monitoring ability (Flanker task), indicating that intensive monolingual language experience also needs to be incorporated into background surveys of bilingual research.

Second, when bilingual cognitive switching advantages are not found, it is necessary to consider whether the bilingual switching experience meets the intensity requirements for advantage emergence. In other words, if no bilingual experience advantage is found, we must further distinguish whether this is due to problems with the bilingual experience itself or insufficient intensity of the bilingual experience. For example, in bilingual cognitive advantage research, bimodal bilinguals (sign-speech) often fail to demonstrate cognitive control advantages compared with monolinguals (e.g., Emmorey et al., 2008). A popular explanation is that because sign and speech rely on different modalities for language perception and production, inter-language competition and conflict are smaller, and language control demands are correspondingly lower. Therefore, bimodal bilingual switching experience may not enhance bilinguals' cognitive control abilities like unimodal speech bilingual switching experience does (for a review see Emmorey et al., 2016). In contrast, the bimodal sign-English SI interpreters mentioned earlier (MacNamara & Conway, 2014) showed enhanced cognitive switching ability after interpreting training. This contrasting result seems to suggest that even if bimodal bilingual switching is less demanding in terms of language control difficulty than unimodal speech bilingual switching, bimodal interpreters can still demonstrate cognitive switching advantages under the high-intensity language switching demands of interpreting activities (MacNamara & Conway, 2014). In fact, using bilingual switching intensity as a factor influencing cognitive switching advantage emergence also aligns with the "supply-demand" hypothesis regarding brain plasticity (Dong & Liu, 2016; Schroeder & Marian, 2017), which posits that when cognitive systems face tasks exceeding current cognitive levels, they increase cognitive resource supply and strive to adapt, thereby achieving improvement.

Finally, regarding bilingual switching control theory, it is also necessary to consider the characteristics of bilingual switching experiences. Bilingual cognitive switching advantages not only reflect cross-domain positive transfer effects but also reveal the essence of bilingual switching control, because only executive functions participating in bilingual switching control may ultimately be enhanced. One reason for contradictory results may be that the tasks or metrics used fail to (comprehensively) reflect the true impact of language switching experience on cognitive switching ability under certain conditions. By comparatively analyzing inconsistent research findings, new metric analysis methods or theoretical hypotheses may be proposed.

6 Conclusions and Prospects

Existing research demonstrates a complex interactive relationship between interpreting and cognitive switching ability. On one hand, interpreting requires the participation of switching ability, as evidenced by switching ability metrics predicting interpreting performance. On the other hand, interpreting experience also enhances interpreters' cognitive switching ability, and at the task-switching level, this enhancement effect may show stage-specific characteristics (from local switching advantages to global monitoring advantages). Further exploration reveals that the manifestation and development of interpreter cognitive switching advantages are influenced by characteristics of language switching in interpreting (e.g., switching intensity, control features). These conclusions contain many hypotheses that require more empirical data for support. Future research can proceed in three directions:

First, focus on the dynamic developmental trajectory and causes of interpreter task-switching advantages. As interpreting training stages progress, interpreters' L2 proficiency, interpreting expertise, and training modality (CI vs. SI) all change. L2 proficiency and interpreting expertise may jointly influence interpreters' cognitive resource allocation efficiency, while different interpreting training modalities imply different cognitive resource allocation patterns, all of which may ultimately lead to changes in task-switching advantages. To fully present potential advantage developmental trajectories and examine the influence of various factors, data from multiple training nodes (e.g., CI learning, professional CI, SI learning, professional SI) across different developmental levels are needed for comparison.

Second, focus on how other executive functions of interpreters influence cognitive switching advantage measurement results. As a basic executive function, cognitive switching ability does not exist in isolation, and language switching in interpreting certainly does not involve only switching ability. As previously mentioned, differences in dependence on working memory capacity may explain why interpreter rule-switching advantages are more stable than task-switching advantages. The essential difference between univalent and bivalent switching tasks also relates to specific executive functions involved. Exploring these issues will help us deeply understand the nature of interpreter task-switching advantages.

Third, focus on the relationship between interpreting processing sub-components and cognitive switching ability. Research in this area is scarce and almost entirely exploratory. Future studies can build on exploratory findings to increase confirmatory studies. Additionally, the interpreting process involves multiple metrics, and currently only some metrics correlate with cognitive switching ability. Future research can decompose the interpreting process and specifically examine correlations between interpreting language switching and cognitive switching ability.

The above review demonstrates that studying the relationship between language switching and cognitive switching ability through interpreting as a special bilingual training mode is an effective approach, providing a good entry point for general bilingual advantage and brain plasticity research that deserves continued in-depth investigation.

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Note: Figure translations are in progress. See original paper for figures.