The more, the better? The influence of multilingualism on cross-situational statistical word learning and mutual exclusivity

Yasmine Tachakourt

Educational Sciences, Humanities, and Languages Research Laboratory (SESHUL), Faculty of Education Sciences, Mohammed V University in Rabat, Morocco

Tianlin Wang

Educational and Counseling Psychology, University at Albany, State University of New York, USA

Abstract

While there is evidence that bilingualism enhances statistical learning and substantially reduces the degree to which learners use mutual exclusivity (ME) constraints, little is known about the role of multilingualism. In this study, we tested ME in monolinguals, sequential-bilinguals, trilinguals, and quadrilinguals using a cross-situational statistical learning task. Participants were familiarized with a mixed set of one-word-to-one-object mappings and two-objects-to-one-word mappings in three consecutive phases, each of which was followed by a test. Results revealed that all language groups learned both mapping types by the end. They also learned more one-to-one mappings than two-to-one mappings. Inconsistent with previous research, bilinguals and monolinguals showed a similar learning trajectory of two-to-one mappings. However, both trilinguals and quadrilinguals outperformed monolinguals. Trilinguals did not differ from quadrilinguals in accepting multiple referents for the same label. Findings suggest that multilingual language experience might enhance cross-situational statistical word learning and ME relaxing ability more than bilingualism.

Keywords: statistical learning; cross-situational learning; multilingualism; bilingualism; mutual exclusivity; word learning

Introduction

Mapping words to their correct referents is an essential part of language learning. A potential problem that learners can face in an ambiguous learning situation where learners are not explicitly cued to the word-object mappings is uncertainty during the mapping process. (for evidence in children and adults see: Aslin & Wang, 2021). This uncertainty is accentuated when words or objects can be mapped to multiple referents (e.g., Au & Glusman, 1990). Recently, statistical learning (SL), the ability to detect and extract co-occurrence regularities from the input, has been proposed as a mechanism that helps learners overcome the challenge of indeterminacy (Yu & Smith, 2007). Learners aggregate information across multiple learning instances in order to reliably map words to their correct referents. To test the SL hypothesis, Yu and Smith (2007) utilized a cross-situational statistical learning (CSSL) paradigm. In their study, adult participants were exposed to multiple scenes consisting of two to three objects displayed at the same time whilst hearing their corresponding labels played in a random order (there was no object-location to word-order correspondence). Each familiarization scene presented different combinations of novel words and their referring objects. Successful learning in this task can only occur if subjects tracked the co-occurrence probabilities between words and objects across different familiarization trials to infer correct mappings. Findings from this study and a number of other successful replications show that both children and adults are capable of tracking cross-situational statistical information to map words to their correct referents (Fitneva & Christiansen, 2011; Hamrick & Rebuschat, 2012; Monaghan & Mattock, 2012; Smith & Yu, 2008; Yu & Smith, 2007).

Early CSSL studies mainly focused on the acquisition of one-word-to-one-object mappings. However, language learning requires that learners form multiple mappings, such as instances with synonymy and homonymy. The ability to resolve many-to-one mapping, is also related to mutual exclusivity (ME) - the tendency to assign a novel label/name to a novel object, rather than assigning it to a familiar one (Markman & Wachtel, 1988). Ichinco et al. (2009) were one of the first to study learners' ability to accept more than one label for the same object and vice versa using a CSSL task. Using a 4X4[1] cross-situational statistical word-learning task, they familiarized participants to a set of one-word-to-one object pairings (1:1 mappings) in the first out of two familiarization phases. In the second familiarization phase, a fifth item (either word or object), which consistently appeared with another item from the previous set, was added to each trial. Two-to-one word-object pairings (2:1 mappings) were introduced to test participants' ability to remap words/objects from the previous set to the new items. The authors found that participants succeeded in learning 1:1 mappings, but failed in learning the second, 2:1, mappings. These results were taken as evidence for a strong preference for ME during the learning process.

However, Kachergis et al. (2009) criticized these results by arguing that a blocking effect was created through the design of the study. When the second items were introduced, they

[1] Using a 4X4 CSSL design entails that in each trial participants will be seeing 4 objects displayed while hearing 4 corresponding words.

were presented together with the first items at a later stage of the learning when learners had already mastered the first mappings of the words/objects. Yurovsky and Yu (2008) also used two familiarization phases in their study, but unlike Ichinco et al. (2009), they removed the first mappings when introducing the second mappings. This manipulation allowed participants to not be blocked by the first association. Results of the study show that participants learned the new associations while retaining the old ones. Kachergis et al. (2009) used a similar paradigm as Ichinco and colleagues (2009) but manipulated the number of occurrences of second mappings. They found that success in learning the second mapping of word-object pairs depended on the number of times participants were exposed to the pairs. Hence, it was concluded that exposure is a key factor in relaxing the 1:1 mapping constraint from ME.

Another factor that could contribute to reduced reliance on ME is experience with multiple languages. Bi-multilinguals' vocabulary compared to monolinguals' is more adaptable and flexible thanks to the increased linguistic variability they deal with. Being bi-multilingual entails forming multiple mappings both within (i.e. homophones) and across known languages (i.e. translation equivalents, false cognates). To efficiently remap words, learners need to adjust their attentional focus, inhibit irrelevant knowledge, and form and store new associations. Since users of multiple languages deal with simultaneous activation of their known languages in their daily linguistic situations (Green, 1998; van Heuven et al., 2011), they have to maintain focus on a target language, suppress other languages, constantly manage conflict and interference as well as remember more words (i.e. translation equivalents). Studies have shown that this added layer of complexity that users of multiple languages contend with improves cognitive functions such as selective attention, inhibition, and working memory (e.g., Bialystok et al., 2014;). This is predicted to have a positive influence on bi-multilinguals' ability to use statistical learning to remap words/objects, especially that these cognitive functions have been previously shown to play an important role in the CSSL task (Soh & Yang, 2021; Vlach & Sandhofer, 2014; Yu et al., 2012).

Recent research by Poepsel and Weiss (2016) examined the influence of late sequential bilingualism on statistical word learning. They found that both monolinguals and bilinguals were able to learn both 1:1 and 2:1 mappings, with bilinguals demonstrating better and faster learning of 2:1 mappings. Similarly, Chan and Monaghan (2019) compared monolingual and bilingual adults in a cross-situational statistical learning task. They observed that both groups successfully learned both types of mappings, with bilinguals showing a steeper learning curve for 2:1 mappings. These findings suggest that learners with greater exposure to language variation rely less on mutual exclusivity in mapping words to objects.

Research on the impact of bilingualism on statistical word learning is growing, but there is limited research on multilingualism (Tachakourt, 2023). It remains unclear whether knowing more languages provides additional benefits in forming multiple mappings using CSSL. In a recent exploratory study, Tachakourt (2023) exposed monolinguals, bilinguals, trilinguals, and quadrilinguals to a joint SL task involving speech segmentation and 1:1 mapping. Quadrilinguals outperformed bilinguals and monolinguals in speech segmentation, while trilinguals showed a different learning pattern, focusing on speech segmentation before mapping. These findings indicate that different language groups exhibit diverse learning curves and strategies. Similar patterns were observed in studies on toddlers by Byers-Heinlein and Werker (2009), where the number of languages, not vocabulary size, predicted the use of ME. Monolinguals relied more on ME, while bilinguals showed partial reliance, and trilinguals showed no preference for ME. Additionally, Papagano and Vallar (1995) found that multilinguals performed better than bilinguals on word learning tasks, and this performance correlated with phonological memory. The findings suggest that individuals proficient in three or more languages may possess distinct characteristics and abilities for learning compared to bilinguals (Herdina & Jessner, 2002; Jessner, 2008).To date, the exact role of bilingualism or even multilingualism on learners' word learning performance remains poorly understood. Providing an understanding of this gap in research should be of great interest to researchers since multilingualism is practically present in every country (Roumaine, 2017). While monolingualism is often considered as the norm, it is, in fact, the exception as more than half of the world's population is bi-multilingual (Grosjean, 1982). In Africa, for example, an overwhelming majority of the continent's population speaks three or more languages as part of their daily lives (Juffermans & Abdelhay, 2017).

In this study, we investigate if increased exposure to linguistic variability enhances the ability to use statistical properties to map and remap words accurately. We compare the learning progress of monolinguals, sequential bilinguals, trilinguals, and quadrilinguals in a task involving 1:1 and 2:1 mappings based on Poepsel and Weiss (2016). Participants are exposed to mixed 1:1 and 2:1 mappings in three familiarization phases, followed by tests. Task difficulty is crucial in how language experience influences learning, and we use challenging 2:1 mappings (e.g., Object A - Word 1, Object B – Word 1) as interlingual homographs are more difficult to learn than translation equivalents across languages, and homophones are more challenging than synonyms within a language. We have two hypotheses: 1) learning will improve with repeated exposure to familiarization materials, and 2) participants' performance will vary based on their linguistic background and task demand. In the 1:1 mapping condition, successful learning is expected for all groups from the beginning. In the 2:1 mapping condition, which is challenging for monolinguals, bilinguals, trilinguals, and quadrilinguals should demonstrate learning success, with the latter two groups outperforming the former two across the learning stages.

Method

Participants

After excluding participants who provided an incomplete submission (N=14), failed catch trials (N=11), and/or showed abnormally long reaction times (N=6), our sample included 80 British University students aged 18-25 and selected based on the information provided on a Language History Questionnaire 3.0 (Li et al., 2019).

All participants in our sample were native English speakers and reported no language related disorders. Each participant was categorized into one of four language groups. They self-rated their language proficiency on a scale from 0-10, 10 being native level. The first group consisted of 20 English monolinguals (female = 15). Based on the questionnaire, these participants had a mean age of 22.10 (SD = 2.31) and self-rated their proficiency in English at 9.60 (SD = 0.68). All of these participants described themselves as strictly monolingual and none reported exposure to a second language.

The second group consisted of 20 English-French sequential bilinguals (female =16) with a mean age of 21.05 (SD = 2.19). Their self-rated English fluency was 9.80 (SD = 0.41). They started learning French at an average age of 7.00 (SD = 3.67) and rated their French proficiency at an average of 7.10 (SD = 1.25).

The third group comprised 20 English-French-Spanish trilinguals (female = 16) with a mean age of 20.85 (SD = 2.06). Their self-rated English proficiency was 9.50 (SD = 0.76). They began learning French at a mean age of 6.90 (SD = 3.58) and rated their French proficiency at 6.70 (SD = 1.26). They began receiving instruction in Spanish at a mean age of 10.25 (SD = 3.49) and self-rated Spanish at 6.05 (SD = 1.19).

The fourth group had 20 English-French-Spanish-German quadrilinguals (female = 11) with a mean age of 21.85 (SD=2.21) and self-rated English proficiency of 9.50 (SD = 0.51). They began learning French at age 5.95 (SD=2.04) with a mean proficiency of 7.95, (SD = 0.95). They started learning Spanish at an average age of 9.90 (SD = 2.02) and self-rated their Spanish fluency at 6.90 (SD = 1.45). German was learned at a mean age of 14.90 (SD = 3.64) and self-rated at a mean proficiency of 5.70 (SD = 1.13).

Stimuli

The present study used a similar experimental design as Poepsel and Weiss (2016). Accordingly, the stimuli consisted of 24 unique word-object pairings created by randomly pairing 18 nonce words with 24 uncommon objects, thereby creating 12 1:1 word-object mappings and 6 2:1 object-word mappings (a single word maps onto two objects). Nonce words were drawn from the English Lexicon Project (ELP) non-word database https://elexicon.wustl.edu. All words were monosyllabic since data from the first experiment in Peopsel & Weiss (2016) indicate that task difficulty increases with the number of syllables in a word. Words were created in a monotone male voice using a text to speech synthesizer. Sound files were then converted into WAV files sampled at 22,050 Hz. All English nonce words were nonwords in all additional languages spoken by participants in this study (i.e. French, Spanish, and German).

Of the 30 objects used in this experiment, 24 were for the main experiment and 6 were employed as attention control trials. All were drawn using complex black and white lines. Sixteen objects were taken from Creel, Aslin, and Tanenhaus (2008), and eleven objects from Tachakourt (2023). Three novel objects were created using MS Paint. All objects were converted to a .jpeg file format with a size of 150 X 150 pixel (see data repository online at https://osf.io/fyedb/?view_only=804e5781aa52473ab85ff234f93cbaab for all stimuli).

The familiarization video consisted of 24 training trials. Since we used a 3X3 design, each of the 24 scenes displayed three objects simultaneously while playing three words serially at an interval of 2 seconds. There was no systematic relation between the temporal order of the spoken words and the spatial location of the objects on the screen. A fixation-cross appeared for 500ms before each trial scene. Trial order was pseudo-randomized: no word-object pair appeared in consecutive trials. All scenes were concatenated using MS video editor. The video stimuli were 2min43sec long and comprised four instances of each 1:1 mapping and two of each of the 2:1 mappings.

The test phase occurred after each familiarization phase and consisted of three tests in total for both 1:1 and 2:1 mappings. The first two tests consisted of 18 2AFC (alternative forced choices) trials, where a word was played and two objects were displayed at the same time: one foil and one target. The order of the trials was randomized for each participant in all tests. All twelve 1:1 mappings were tested once in both tests, but each test tested half of the 2:1 mappings. In test 1, the six 2:1 mapping trials consisted of half of the primacy mappings (the first word-object mapping encountered during familiarization), and half of the recency mappings (the second word-object mapping encountered). The other half of the primacy and recency mappings was tested in the second test. Each possible referent was tested once across the first two tests, and the order was pseudo-randomized and counterbalanced across participants. This measure was taken to make sure that participants were not explicitly cued to the presence of multiple mappings for some objects and not reinforced for one mapping over the other. The third test assessed all 1:1 mappings and all 2:1 mappings, and included 36 trials. Each of the twelve 1:1 mappings was tested twice. Each of the 2:1 mappings was tested once.

Attention control trials consisted of six 2AFC trials. Each trial played one of the nonce words heard in familiarization and displayed two objects: one is a correct referent seen in familiarization and the other is a distractor never encountered before.

Procedure

The experiment was administered online. Participants were instructed to do the task on a computer in a quiet room with a headset on. They were informed that they would hear and see multiple objects simultaneously, all part of a "nonsense" language. They were also told that their task was to match the objects with their correct labels/names across multiple trials.

Once they gave consent to participation, the experiment started. Participants completed three familiarization phases, each of which was followed by a test phase. In each of the 2AFC test trials, they had to press '1' or '2' to choose between the distractor and the correct referent mapping of the played word. After finishing all 36 trials of Test 3, participants completed six attention control trials. Participants were given as much time as needed to make each response.

Results

We transformed accuracy data into percentage correct since the two mapping conditions consisted of different numbers of trials.

We first tested whether the four language groups have successfully learned the label-reference pairings in the two types of mapping conditions. Given that there is ample research showing that both monolingual and bilingual adults can learn word labels in the 1:1 mapping condition (e.g., Poepsel & Weiss, 2016), and our expectation that the trilinguals and quadrilinguals may have additional cognitive advantage compared to the monolinguals and bilinguals, we had expected all groups to be able to learn in the 1:1 condition. For the 2:1 mapping condition, we anticipated successful learning from the groups who knew more than one language. A series of one-sample t-tests (see Table 2 for a summary) across the three time points showed that for the 1:1 mapping condition, monolinguals did not successfully learn the word labels after the first familiarization phase (at Time 1) but improved in the second familiarization phase and were performing above chance at Time 2 as well as Time 3. By contrast, bilinguals, trilinguals, and quadrilinguals all succeeded on this task after the first familiarization phase.

For the more challenging 2:1 mapping condition, monolinguals did not perform at above chance level until after the 3rd familiarization phase. Bilinguals were similar in their performance and only scored above chance by Time 3. Both trilinguals and quadrilinguals behaved similarly and were able to learn the mappings from Time 1.

Our main question was whether learning the 1:1 and 2:1 mappings over time differed as a function of language background. To test this question, we ran a three-way mixed ANOVA with Condition (within: 1:1, 2:1) X Group (between: monolingual, bilingual, trilingual, quadrilingual) X Time (within: Time 1, Time 2, Time 3) and found a significant main effect of Time [$F(2, 75) = 48.926$, $p < .0001$, partial $\eta^2 = .566$], a significant main effect of Condition [$F(1,76) = 20.985$, $p < .0001$, partial $\eta^2 = .216$], and a significant interaction between Time and Condition [$F(2, 75) = 4.191$, $p = .019$, partial $\eta^2 = .101$]. To better understand these results, we asked whether the four language groups performed differently at each time point using general linear models. We regressed accuracy on Group and found no difference in performance at Time 1 for either the 1:1 mapping [$F(3,76) = 1.918$, $p = .134$] or the 2:1 mapping [$F(3,76) = 1.827$, $p = .149$]. No learning difference as a function of language background was observed after the initial familiarization phase.

The same analyses were run for Time 2, and results showed that there was an effect of Group [$F(3,76)=4.021$, $p = .010$, adjusted $R^2=.103$] for the 1:1 mapping condition as well as for the 2:1 mapping condition [$F(3,76)=2.792$, $p = .046$, adjusted $R^2=.064$]. Post hoc analyses on the 1:1 mapping condition with Bonferroni correction revealed a marginal difference between monolinguals and quadrilinguals, $p = .055$, and a marginal difference between bilinguals and quadrilinguals, $p = .055$. For the 2:1 mapping condition, the post hoc tests did not yield significant results.

For Time 3, regressing accuracy on Group showed significant difference in both the 1:1 condition [$F(3,76)=6.947$, $p < .001$, adjusted $R^2 = .184$] and the 2:1 condition [$F(3,76)= 4.651$, $p = .005$, adjusted $R^2 = .122$]. Bonferroni adjusted post hocs showed that for the 1:1 mapping condition, quadrilinguals outperformed monolinguals, $p = .001$, and bilinguals, $p = .001$. In the more challenging, 2:1 condition, both trilinguals and quadrilinguals outperformed monolinguals, $p = .001$, $p = .042$, respectively; while the multilinguals groups did not differ from each other.

Finally, we asked whether there was a correlation in performance across the familiarization phases. For the 1:1 mapping condition, accuracy at Times 1 and 2 was significantly correlated [$r=.301$, $p = .007$], and accuracy at Times 2 and 3 was also significantly correlated [$r=.485$, $p <.001$]. The initial learning and the final learning results at Times 1 and 3 were also correlated [$r= .237$, $p =.034$]. For the 2:1 mapping condition, Time 1 and 2 accuracy was not correlated [$r = .119$, $p =.294$]; Time 2 and 3 [$r=.482$, $p < .001$] as well as Time 1 and 3 were significantly correlated [$r=.279$, $p = .012$]. These patterns demonstrate that there was consistency in how participants performed among the familiarization phases.

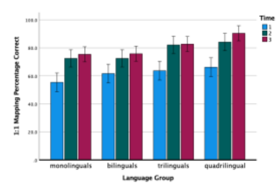

Figure 1a. Mean mapping accuracy by language group over three familiarization phases in the 1:1 mapping condition

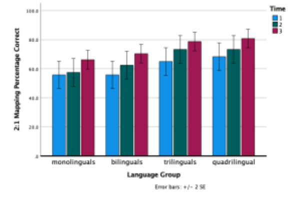

Figure 1b. Mean mapping accuracy by language group over three familiarization phases in the 2:1 mapping condition

Table 1. Summary of one-sample t-tests across language groups and conditions at each time point.

	Condition	1:1 Mapping			2:1 Mapping		
Language Group	**Test Statistics**	**T 1**	**T 2**	**T 3**	**T1**	**T2**	**T3**
Monolinguals	t	1.530	5.736	8.057	1.161	1.339	5.325
	p	.142	<.001	<.001	.260	.197	<.001
	d	.342	1.283	1.802	.260	.299	1.191
Bilinguals	t	4.765	6.469	9.403	1.277	2.775	5.517
	p	<.001	<.001	<.001	.217	.012	<.001
	d	1.066	1.446	2.103	.286	.621	1.234
Trilinguals	t	4.067	12.768	10.546	3.111	5.272	10.262
	p	<.001	<.001	<.001	.006	<.001	<.001
	d	.909	2.855	2.358	.696	1.179	2.295
Quadrilinguals	t	4.225	16.383	32.333	4.067	5.272	9.799
	p	<.001	<.001	<.001	<.001	<.001	<.001
	d	.945	3.663	7.230	.909	1.179	2.191

Discussion

We compared four language groups: monolinguals, sequential bilinguals, trilinguals, and quadrilinguals to determine whether there were differences in the learning of 1:1 and 2:1 mappings in a cross-situational statistical word learning task as a function of multilingualism. After exposure to a mixed set of 1:1 and 2:1 mappings in 3 consecutive familiarization phases and completing 2AFC tests after each familiarization phase, participants across the four groups learned both 1:1 and 2:1 mappings, with better learning in the 1:1 mappings. Interestingly, quadrilinguals outperformed both monolinguals and bilinguals on the 1:1 mappings, but did not differ from trilinguals. For 2:1 mappings, trilinguals and quadrilinguals outperformed monolinguals, but did not differ from bilinguals.

Our results indicate that the learning of 1:1 mappings was facilitated by both the ME constraint and language experience. The fact that all groups learned above chance more often on the 1:1 mappings is perhaps due to learners' general preference for ME, and difficulty to suspend this constraint. This finding is in line with results reported in previous studies (e.g., Benitez, et al., 2016; Poepsel & Weiss, 2016; Yurovsky & Yu, 2008). In a study conducted by Chan and Monaghan (2019), the reverse trend was reported as both groups learned more 2:1 mappings than 1:1 mappings. However, this result could be due to the imbalanced number of objects for each of the mappings as more objects mapped onto two words. In addition, our results suggest that knowledge of an additional language aids the learning of 1:1 mappings as we found that bilinguals, trilinguals, and quadrilinguals succeeded in learning the pairings after only one familiarization phase, faster than monolinguals. Furthermore, quadrilinguals significantly outperformed both monolinguals and bilinguals in learning this type of mapping. This superior performance of the bilinguals and multilinguals is surprising, especially that the research we have so far converges towards the idea that experience with multiple languages does not necessarily influence the most basic forms of statistical learning such as tracking one regularity across multiple learning instances (Kittleson et al., 2010; Peopsel & Weiss, 2016).While more data is required to draw a firm conclusion, our results suggest that multilingualism (i.e., knowing more than two languages) might further improve learning accuracy in cross-situational statistical learning. We propose that the enhanced working memory and selective attention that multilinguals possess (e.g., Bouffier et al., 2020) might facilitate detection and recall of patterns in the input further enhancing cross-situational statistical learning of 1:1 mappings.

Another interesting finding was that multilingualism, but not bilingualism, enhanced performance on 2:1 mappings as both trilinguals and quadrilinguals required fewer familiarization phases and shorter exposure time and were more accurate than monolinguals, whereas bilinguals only showed an advantage over monolinguals after two familiarization phases. Trilinguals and quadrilinguals both succeeded on 2:1 mappings after just one familiarization phase and, thereby, suggesting a greater capacity to suspend the ME constraint from the beginning. Learning 2:1 mappings is not only boosted by enhanced selective attention and working memory, but also inhibition (Bouffier et al., 2020; Weiss et al., 2010; for a review see Bialystok, 2015). Remapping words necessitates some degree of inhibition whereby the first learned word-object mapping is suppressed, allowing the brain to associate the word to another object. The more languages learners speak, the more inhibition needed to suppress competition caused by translation equivalents and interlingual homographs. This sharper inhibitory control might have contributed to the efficient tracking of multiple regularities and, in turn, the successful remapping observed in multilinguals. Furthermore, quadrilinguals did not only outperform monolinguals, but also bilinguals, indicating that mastery of four languages, rather than two, substantially enhances learners' ability to track multiple structures and reliably remap word-object referents. The increased exposure to linguistic variability, which quadrilinguals contend with, encourages largely the suspension of ME and acceptance of many-to-one mappings.

This is consistent with McMurray and colleagues' (2012) computational model, which posits that the number of translation equivalents available in the input guides the extent to which learners can relax ME. Thus far, it can be argued that using multiple languages helps learners develop a prior expectation to change in a learning environment, which in turn sharpens their ability to detect changes in new environments.

Although both trilinguals and quadrilinguals outperformed bilinguals and monolinguals on the 2:1 mappings at Time 3, only quadrilinguals exhibited superior performance over both monolinguals and bilinguals at Time 2. Notably, quadrilinguals consistently outperformed the other groups on the 1:1 mappings throughout the study. The consistent superiority of quadrilinguals raises questions about the role of motivation in their statistical learning. It is worth mentioning that quadrilinguals in this study learned a language during adolescence (M=14.90; SD=3.64), whereas the other groups acquired their languages during childhood. Adolescents and adults, driven by motivation (Dörnyei & Ushioda, 2011), may exhibit enhanced statistical learning abilities compared to children (Werker & Hensch, 2015) due to their awareness of the benefits associated with multilingualism. Motivation can also influence neural mechanisms underlying statistical learning, with evidence suggesting that motivated individuals demonstrate improved neural plasticity and information processing efficiency (Park & Bishof, 2013), potentially aiding quadrilinguals in extracting and learning statistical regularities in the CSSL task..

The results reported in this study on the learning trajectories of 2:1 mappings demonstrated by monolinguals and bilinguals are inconsistent with Chan and Monaghan (2019) who found a bilingual advantage in the learning of 2:1 mappings. While our monolingual and bilingual participants were from the same age group and reported similar L1 and L2 fluency compared to those in the other studies, the nature of the 2:1 mapping task itself was different across the studies. Participants in Chan and colleagues (2019) had to map two words to the same object, while ours mapped two objects to the same word. This could have led to different learning outcomes; especially that interlingual homographs, for example, mapping the word "*Hell*/*hell*" to two different referents- referring to light in German, and to a place of pain and turmoil in English, are considered as more challenging to learn than translation equivalents such as mapping the German word "*Kartoffel*" and the English word "*potato*" to the same referent- a type of vegetables Benders. et al. (2011) found that false friends are harder to learn- even more so when paired with cognates. Future work could explicitly study whether learning two-words-to-one-object mappings and learning two-objects-to-one-word mappings in a cross-situational paradigm can lead to differences in relaxing ME within and across different language groups.

Surprisingly, despite the shared similarities of our experimental designs, our results do not tally with those of Poepsel and Weiss (2016), who reported a statistically significant advantage in late sequential bilinguals when mapping one word onto two objects. We suspect that this difference could have been steered by differences in the rate of presentation. During the familiarization phase of our study, participants heard three words played serially while seeing three objects displayed at the same time in each scene. In this study, nonce words were played serially at 2s intervals while they were played at 3s intervals in Poepsel and Weiss's study. This meant that our participants had a shorter visual exposure time to the objects, which could have increased task difficulty leading to a similar performance between bilinguals and monolinguals. Previous works suggest that changes in presentation rates of both auditory and visual stimuli affect performance. It was found that performance improved at fast presentation rates for the auditory stimuli, but worsened for the visual one. The opposite was also true as performance worsened at slow presentation rates for the auditory stimuli but improved for the visual one (e.g., Conway & Christiansen, 2009; Emberson et al., 2011).

In the current study, there were several limitations that should be considered in future research. Firstly, conducting the study online introduced challenges in ensuring a consistent experimental environment for all participants. Additionally, participants' self-rated language proficiency may have been biased. Administering comprehensive language proficiency tests online for multiple languages was impractical due to time constraints and potential impact on participants' attention span (Dandurand et al., 2008).

Conclusion

This paper argued that monolinguals, sequential bilinguals, trilinguals, and quadrilinguals were all able to use statistical information available in the input in order to learn both 1:1 and 2:1 word-object mappings. Nevertheless, the ability to suspend ME and assign two objects to the same label was greater in trilinguals and quadrilinguals who, unlike bilinguals, outperformed monolinguals. Importantly, our results show that using four languages could sharpen statistical learning ability and largely relax the constraint of ME. Overall, our findings demonstrate a positive effect of multilingual language experience on cross-situational word learning. They also indicate that any generalizations about the bilingual and multilingual populations might be misleading. Nevertheless, further work is certainly required to develop and confirm these initial findings as well as disentangle the complexities of multilingualism and its impact on statistical word learning.

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