2021

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THE JOURNAL OF ASIA TEFL
Vol. 18, No. 2, Summer 2021, 451-467
http://dx.doi.org/10.18823/asiatefl.2021.18.2.5.451

The Journal of Asia TEFL

http://journal.asiatefl.org/

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A Meta-analysis: Shape of Age Effects and Second Language Grammar Acquisition

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This study reports findings of a meta-analysis on the effects of the age of first exposure, known as the age of onset (AO), on the acquisition of morphosyntax in a second language (L2). Several studies report restrictive effects of AO on L2 grammar acquisition (Abrahamsson, 2012; DeKeyser et al., 2010; Qureshi, 2016); however, there is a disagreement about the way sensitivity to second language acquisition declines (Birdsong, 2009; Long, 2013). Researchers disagree about the nature of the decline and argue whether the decrease that occurs in learners' ultimate proficiency in the second language is gradual and continuous or gradual but followed by a plateau, without further decline. To explore the nature of AO, 29 samples from 14 studies were analyzed. The results revealed a large effect size1 (d = 1.13, SD = .06) for the impact of AO on ultimate proficiency in L2 morphosyntax. However, for the disaggregated data (i.e., when earlier & late learners are separated), a linear decline was observed for the 6 to 16 age-group (21 samples), while a flattening of the regression line was detected for the 17 to 24 age-group (8 samples). More importantly, the findings revealed two different shapes of decline based on participants' first language and the target L2. Overall, the findings support a bounded critical period for second language acquisition and indicate the typological distance between the two languages as a major influencing factor.

Keywords: age effects, age of onset, critical period, typological distance, ultimate attainment

Introduction

One major individual feature widely explored in language research is the age at which learners are exposed to a second language in their environment. It is generally believed that there is a restricted phase before adulthood when optimal attainment in an L2 is possible, and after this period, full competence in an L2 is not achievable. In language research, this phenomenon is theorized as the critical period hypothesis (CPH), which suggests that there is a certain "window of opportunity" in which human beings are particularly sensitive to learning a language (DeKeyser et al., 2010; Flege et al., 1999; Granena & Long, 2013; Johnson & Newport, 1989; Moyer, 1999; Seol, 2005; Singleton & Munoz, 2011). After this critical phase, sensitivity to language acquisition declines. Considering the general nature of the decline and individual variations in the cognitive abilities of L2 learners, Long (2013) prefers the term sensitive period (SP) to the CP. However, the term CP has almost become a standard term for describing age effects in L2 research.

The concept of the CPH was first observed in animals, and instances of a critical period have been reported for song learning in chaffinches (DeGroot, 2011) and visual development in cats (Hubel &

[1] Plonsky and Oswald (2014) suggest 0.4 as a small, 0.7 as a medium, and 1, as a large effect size in second language research.

Wiesel, 1956). For humans, the CPH has been confirmed for those who had a delayed exposure to L1. With regard to L2 acquisition, restrictive effects of AO have been established for late learners. These effects have been reported for morphosyntax and pronunciation (e.g., DeKeyser et al., 2010; Flege et al., 1999; Gitsaki & Althobaiti, 2010; Granena, 2012; Johnson & Newport, 1989; Moyer, 1999; Seol, 2005). Here it is important to mention that the negative effects of an older AO for second language acquisition (SLA) are supported for the L2 contexts where learners are immersed in the target language settings, for example, a Chinese speaker learning English in the U.S. However, similar restrictive effects of an older AO are not confirmed for language learning in foreign language (FL) backgrounds where a target language is not available in the surroundings, as the case would be with Arabic in the U.S. (for more details, see Lee, 2020). Nonetheless, in L2 contexts, most studies have reported an increasingly negative correlation for L2 learning ability with an increase in age, which means that language learning ability declines as we grow older. However, when the language acquisition declines and how the decline proceeds (i.e., continuously or gradually) are vital yet unresolved questions. The following section offers an overview of the previous research exploring the shape of age effects.

Literature Review

With respect to the way language acquisition ensues, AO effects are analyzed in three categories depicted in Figure 1.

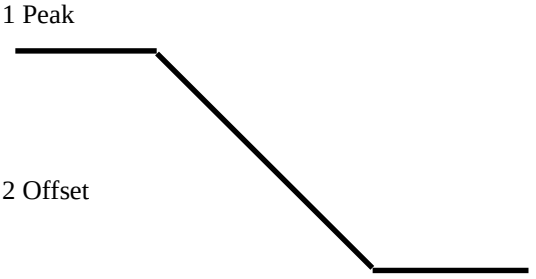


Figure 1. The shape of age effects on SLT.

Figure 1 portrays the hypothesized CP-shape of the critical period for SLA. Point 1 shows a plateau to represent the period of peak sensitivity. According to the CPH, the ultimate attainment in an L2 is possible only within the limits of the period of the peak sensitivity (Granena & Long, 2013). This phase is suggested to sustain a constant sensitivity to language acquisition (Bornstein, 1989). After this phase, sensitivity to language acquisition declines. However, how the decline proceeds is central to the confirmation or rejection of the CPH. If a decline occurs and continues throughout life that would document a general decrease in human ability to learn a language. To confirm the CPH, there needs to be a non-linear decline; a discontinuity in language proficiency should be evident (DeKeyser, 2012) as presented in point 3, and a flattened line should be witnessed after the break (Birdsong, 2006). A figure representing the shape of the CP is generally referred to as a stretched Z as depicted in Figure 2 (for more details, see Granena & Long, 2013).

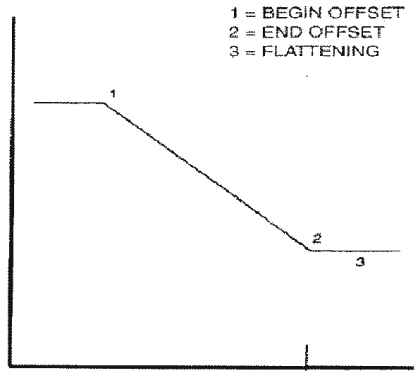


Figure 2. Stretched representation for the shape of age effects from Birdsong (2005, p. 113). Printed in J. Kroll & A. de Groot (Eds).

A discontinuity as illustrated at point 2 in Figure 2 represents an end to the critical phase needed for language acquisition, and after this point, AO should not be a significant predictor of language acquisition.

As the CPH is concerned with the 'end-state' or 'ultimate attainment' in an L2, research with reference to age effects is focused more on the decline in the ability to learn a language with an increase in age. Several plausible explanations for this decline have been proposed, such as inaccessibility to the universal grammar (UG; Eubank & Gregg, 1999; Noroozizadeh, 2006) and interference from pre-existing L1 (Pallier, 2007). However, one explanation that seems to correspond well with a maturational explanation of the CPH is the "loss of cortical circulatory" as proposed by Pinker (1994). Simply put, there is a specific faculty in the brain that is instrumental in language acquisition; this faculty and its function (i.e., language acquisition) reach the highest level of sensitivity at a certain age (e.g., 6 years), and after this, a decline begins in language learning ability that ends at puberty with a corresponding expiration of the mental faculty. This explanation closely matches the CPH as it posits a specific period of sensitivity to language input that ceases at puberty, and a decline in language acquisition does not continue after this period.

Several studies have confirmed an older age as a constraint on the ultimate attainment in L2 grammar (e.g., Abrahamsson, 2012; Seol, 2005). This finding is more consistent for the aggregated groups (i.e., earlier & late learners combined) that obtained a strong negative correlation for AO and L2 grammar. For example, Johnson and Newport (19989) reported a strong negative correlation (r = -.77) between AO and English morphosyntax for Chinese and Korean L2 learners. Furthermore, Dekeyser (2000) reported a negative correlation (r = -.63) for Hungarian L2 learners, and Birdsong and Molis (2001) observed a similar strong negative correlation (r = -.71) for Spanish learners. A meta-analysis by Qureshi (2016) also reported a pooled effect size of (r = -.55) for 16 studies with a correlational design and (d = .68) for 20 studies with a group comparison design conducted in the SL contexts. These studies support superior language acquisition ability in younger learners.

However, for the disaggregated groups (i.e., earlier & late learners separated), inconsistent findings have been reported. Johnson and Newport (1989) in their influential study explored AO effects on acquisition of L2 English morphosyntax by 46 Chinese and Korean learners. Despite their results supporting an overall strong negative correlation between AO and L2 grammar acquisition, when groups were split into early and late learners, a non-significant correlation (r = -.16) was observed for the late starters, which indicated no systematic relationship between AO and L2 proficiency. However, Johnson and Newport (1989) construed it as a piece of evidence for age effects, suggesting that "performance did not continue to decline with increasing age" (p. 90). This was contrary to the strong and significant negative correlation (r = -.87) observed for early starters, indicative of a decline in proficiency with increasing age among the early learners.

The inconsistent results for the split groups have been reported in DeKeyser (2000) as well. While the study reported an overall significant negative correlation (r = -.63, p < .001) for 57 Hungarian learners of English as an L2, it reported no systematic pattern of correlations when groups were separated in younger and older learners. Contrary to the Johnson and Newport's (1989) findings of significant AO effects for the early learners,

the study by DeKeyser (2000) found no significant correlations between AO and ultimate attainment for either the early starters (r = -.24, *ns*) or the late starters (r = -.04, *ns*) when the groups were separated.

Another study that reported relatively opposite patterns of correlations between AO and acquisition of L2 morphosyntax is Birdsong and Molis (2001). This study replicated Johnson and Newport (1989) with L1 Spanish speakers (n = 61) who were divided in early (n = 29) and late (n = 32) starters based on their AO (i.e., 16). Consistent with Johnson and Newport, this study observed an overall strong negative correlation (r = -.77). However, when the groups were divided, the correlation between AO and acquisition of L2 was weak (r = -.24, *ns*) for the early starters but strong (r = -.69) for the late starters. This finding for the disaggregated groups in Birdsong and Molis (2001) presents a reversed pattern compared to Johnson and Newport (1989) who reported a strong and significant correlation (r = -.87) between AO and grammar scores for the early starters, and a weak and non-significant correlation for the late arrivals (r = -.16). The reversed pattern of correlations observed in the two studies is displayed in Figure 3.

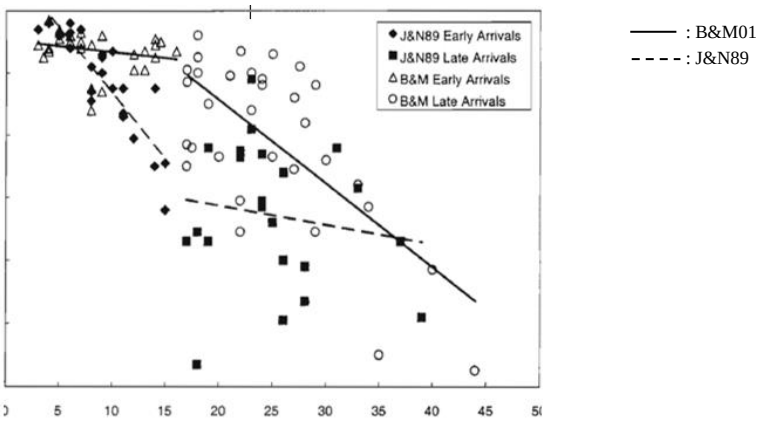


Figure 3. The reversed pattern of the shape of age effects for split groups in Johnson and Newport (1989) and Birdsong and Molis (2001). Data are from Birdsong, D. (2005, p. 118). Printed in J. Kroll & A. de Groot (Eds).

The decline displayed in Figure 3 shows a geometrically reversed shape for the age effects in Birdsong and Molis (2001) as compared to Johnson and Newport (1989). In Johnson and Newport (1989), a steep declining line is witnessed for the early arrivals, followed by a relatively flat regression line for the late learners; while in Birdsong and Molis (2001), the shape of the age effects is nearly flat for the early learners, followed by a sharp decline for the late learners. In other words, in Johnson and Newport (1989), a decline in language proficiency started early on, around the age of 8, and it flattened out at around AO 16. Beyond this point, the AO did not show a significant effect on further language proficiency. In contrast, in Birdsong and Molis (2001), learners demonstrated a relatively higher proficiency until the age of 16, followed by a sharp decline thereafter.

Not only an inconsistent shape for the AO effects has been reported in the previous literature, but also a different point for the discontinuity has been suggested. For example, Bialystok and Hakuta (1994) reanalyzed Johnson and Newport (1989) and found that the best linearity would be achieved if data were cutoff at age 20. In their reanalysis of Johnson and Newport (1989), they moved the cutoff age for the early and late starters to 20 years, and a significant correlation was observed between AO and L2 acquisition for the late group (r = -.50). Birdsong and Molis (2001) conducted a similar re-analysis and observed a significant correlation for their late starter group when they moved the cutoff points at different ages between 15 to 27.5 years.

Relatively more recent studies also seem to report divergent findings on the AO effects. Hartshorne et al. (2018) explored the nature of AO effects on L2 morphosyntax with an extra-ordinary sample of 558,265 participants. Using a Facebook-based grammar quiz, Hartshorne et al. (2018) collected data from L2 learners who had immersive, non-immersive, and bilingual exposure to L2. The study proposed that the critical ability to learn a second language is well-preserved until the age of 17 years. Hence, learners exposed to an L2 until the age of 12 and 9, in immersion and non-immersion conditions, may still demonstrate grammar proficiency similar to child bilingual learners. After these ages, a decline in the

learning ability becomes more evident because language learning is a time-taking process, and those exposed to an L2 at a later age simply run out of time to make the best use of this critical phase. However, as the study proposes an omnibus cut-off age of 17.4 years for the three groups of learners with very different nature of exposure to L2 (i.e., immersion, non-immersion, & bilingual), the findings must be interpreted with caution. Moreover, the study reported exploring a continuous model (e.g., *Figure S2;* S, in Supplementary Materials in Hartshorne et al., 2018), without stating its outcomes. Because a discontinuous function is argued for in their study, it would have been more informative if the outcomes of the continuous model were also explored and reported in the paper. Furthermore, the findings of Hartshorne et al. (2018) are also in contrast to the outcomes reported in Abrahamsson et al. (2018). Abrahamsson et al. (2018) reviewed two of their previous studies (i.e., Abrahamsson & Hyltenstam, 2009; Abrahamsson, 2012) and proposed two cut-off points in the proficiency in L2 morphosyntax at age 6-7 years and 12-13 years. These findings were based on the significant negative correlations (r = -.57 & -.60) obtained for the younger groups (i.e., AO > 12 & > 15) in the two studies.

With the backdrop of divergent findings discussed above, it can be stated that the findings of the impact of AO on the shape of ultimate attainment in L2 morphosyntax are inconclusive. The current meta-analysis is an attempt to explore more conclusive findings about the effects of AO on ultimate proficiency in L2 morphosyntax.

The Current Study

In this meta-analysis, a very extensive search and review of the previous literature on the topic was conducted. However, as the main aim of the current study was specific, which was to identify the shape of the age effects for L2 grammar knowledge, extreme caution was taken to include only those studies that were similar in (1) learning context, (2) dependent variable (i.e., proficiency in grammar), and (3) in research design (i.e., group-comparison). In certain cases where group-comparison design was not used, for example DeKeyser (2000), means and *SD*s for younger and older groups were used to compute effect sizes. Due to these very specific inclusion criteria, and then because of further data screening for analysis - explained in a later section - the final analysis included 29 samples from 14 studies.

Research Questions

To explore the nature of age function, the current study investigated the following research questions:

1. Does an accumulated body of research show a gradual and continuous decline in grammatical proficiency or a gradual decrease followed by a plateau?
2. What are the age correlates of such gradual-continuous or gradual-flattened proficiency in L2 grammar?

Method

Literature Search

Following the standard guidelines (e.g., Plonsky & Oswald, 2012), a detailed search was conducted on the topic of interest, which was later narrowed down to the topic of interest for analysis. The literature search started with Google and Google scholar using keyword/phrase technique. Several key words/phrases were used. A few sample key-phrases included: *age and second language proficiency, age constraints on second language learning, age and ultimate attainment, age effects in second language*

acquisition, age of onset and native-like L2 attainment, the critical period for language acquisition, the critical period for language learning, the sensitive period in language learning, the critical period hypothesis and second language acquisition, maturational constraints on language acquisition, language acquisition at different ages, the sensitive period in language development, the problem of age in a second language, and *the robustness of critical period.*

After searching Google and Google scholar, the same phrases were entered in the following academic databases: *Academic Search Complete, JSTOR, Linguistics and Language Behavior Abstracts (LLBA), PsycARTICLES, PsycINFO, Science Direct, SAGE Journals, The Educational Resource Information Center (ERIC),* and *Web of Knowledge*

The studies were also explored in the following journals: *Annual Review of Applied Linguistics*, *Applied Linguistics, Applied Psycholinguistics, Cognitive Psychology, International Review of Applied Linguistics in Language Teaching, Journal of Memory and Language, Journal of Psycholinguist Research, Language Learning, Modern Language Journal, Studies in Second Language Acquisition, Second Language Research, TESOL Quarterly, and The Canadian Modern Language Review.* While exploring journals for the potential studies, all their previous issues were individually checked. After any individual study was identified as suitable for inclusion, its references were thoroughly scanned to obtain more sources for possible inclusion.

This exploration resulted in collecting 90 studies that explored age effects on second language acquisition. Before any study could be included in the analysis, each study was individually checked for the inclusion criteria detailed below.

Inclusion Criteria

This meta-analysis included all the studies that:

(a) investigated the relationship between age of onset and L2 grammatical proficiency,
(b) were conducted in SL contexts, and
(c) provided needed information (*M, SD, t-test, f-test*) to extract an effect size.

As the age effects are not confirmed for the FL contexts, studies conducted only in the SL settings were included. For calculating effect size, Cohen's *d* was chosen because a majority of studies with group comparison design had provided means and SDs for different age groups (e.g., 0-5; 6-11) included in the study, making it feasible to compute an effect size *d* for different age cut-offs.

Exclusion Criteria

After securing the potential studies for inclusion, their abstracts, introductions, methods, and results were thoroughly examined. Studies with missing data (e.g., means, *SD*s) were dropped from the analysis. Also, studies focusing on aspects of language other than L2 grammar (e.g., lexis, phonology) were not included in the analysis. As the main aim of the current meta-analysis was to ascertain age effects for L2 learners, studies that compared native speakers with advanced L2 learners were excluded from the investigations. Similarly, if a native group was present along with early and late learners in a study, the native group was excluded from the analysis, while date for the learner groups were retained. Studies with the correlational design were also excluded as these provided either an omnibus group correlation or separate correlations for younger and older age groups, without specifying AO effects for different age breakdowns (i.e., 1-5, 6-10), which restricted meta-analyzing AO effects along the age continuum for studies with correlational designs. Moreover, if a study used several instruments (e.g., an oral production task, a grammaticality judgment task; GJT), data for all other instruments except those that examined grammar were excluded.

Variables: Independent and Dependent

A detailed coding scheme was developed to identify the independent and dependent variables. The coding scheme comprised three major sections. The first category, study identification, contained information about author(s), title, year, and type of publication. The second section, methods, included participants' L1 and L2, information about sample size, participants' age of arrival, age at testing, types of instruments (e.g., GJT, interviews), cut-off ages for comparison, and instrument reliability. The last category, results, included means, SDs, *t*-values, *f*-values, and *ds.*

Age of onset was coded as the independent variable. Based on the AO, participants were coded as either early or late starters. Performance on any task assessing L2 grammar knowledge was coded as a dependent variable. In this case, all the studies included in the analysis came from SL contexts and used some type of GJT, except Patkowski (1980), which used an interview-based grammar rating task for data collection. Table 1 presents the main methodological features of the studies included in the analyses.

TABLE 1
Methodological Features of the Included Studies

Aspects	Subcategories
Total samples (sample after screening)	38 (29)
Total participants from the included samples	1533
Context	SL
Date of publication	1993-2012
First Languages	
Chinese	6
Chinese & Korean	4
Chinese-Spanish	3
Greek	1
Heritage Spanish-English	1
Hungarian	1
Korean	3
Korean-English	1
Many	2
Russian	2
Spanish	4
Second Languages	
English	18
Spanish	7
Swedish	2
Hebrew	1
Instruments	
GJTs	28
GJT timed and aural	23
GJT untimed and aural	3
GJT untimed and written	1
Interview-based grammar rating	1
Cut-off ages	
6	1
7	1
8	2
9	2
11	3
12	2
14	1
15	5
16	4
17	2
22	2
23	2
24	2

Length of Residence (LOR) and Age at Testing (AaT)

Length of residence and age at testing were not analyzed for the studies included in the current analysis becaue previos research reports no significant effects of LoR beyond five years of exposure (e.g., Dekeyser et al., 2010). Similarly, participants' age at testing was excluded from further analysis as this was beyond the scope of the current paper.

Random effects model and weighting of effect sizes

A random effects model was used to analyze the data. A random effects model is used when studies have considerable commonality, although moderators might be present. It examines systematic variation in effect sizes (ESs) and sampling error (Borenstein et al., 2009). An inverse variance weighting was used to weight effect sizes. This approach assigns more weight to studies with a greater sample size and smaller *SD* as compared to studies with smaller sample sizes and larger *SD* (Oswald & Plonsky, 2010).

Data screening

Studies with very large effect sizes can have biasing effects on the outcome in a meta-analysis (Bernard et al., 2014). In order to check for extreme outliers, funnel (Figure 4) and forest plots (Figure 5) were analyzed. Two samples from Johnson (1992) and Shim (1993) had ESs of 4.4. and -2.4, respectively; hence, these were considered as outlier and removed from further analysis. Bernard et al. (2014) also recommend checking against studies with poor quality. In the current case, as the effects of AO on L2 acquisition have been widely acknowledged for SL contexts, any study reporting no age effects, or a negative effect size was removed. Thus, seven samples, coming mainly from three studies were excluded from further analysis; these exclusions are circled in figures 4 and 5. As a result of this screening, the number of samples contained in the final analysis was curtailed from the initial 38 to 29 samples, coming from 14 studies.

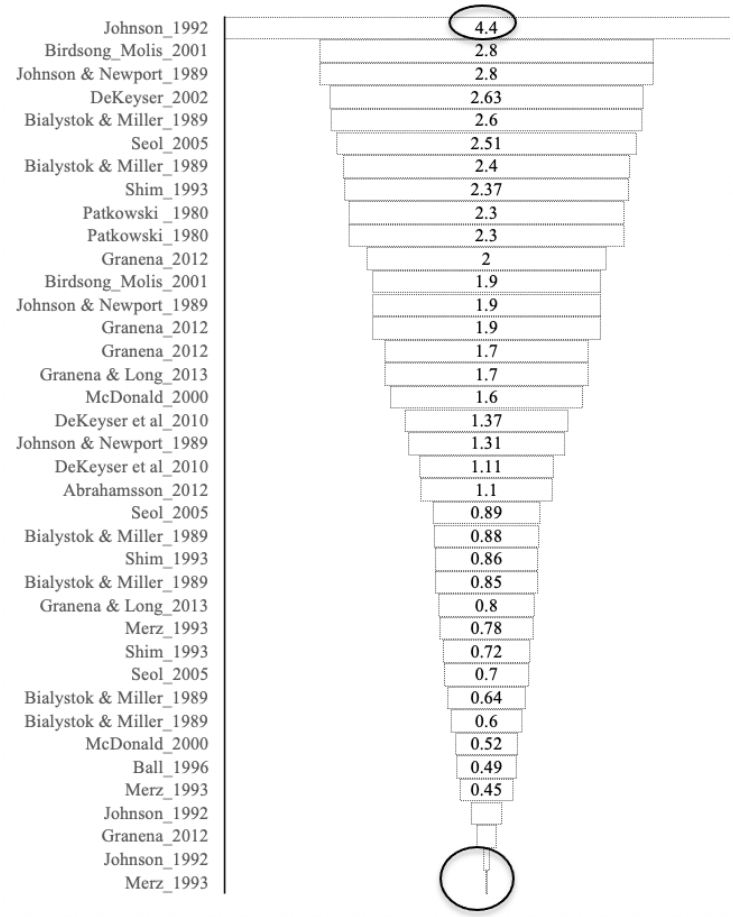


Figure 4. Funnel plot for spotting extreme effect sizes.

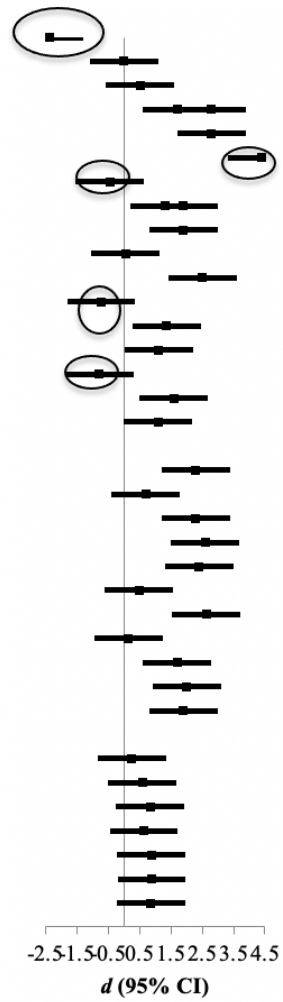


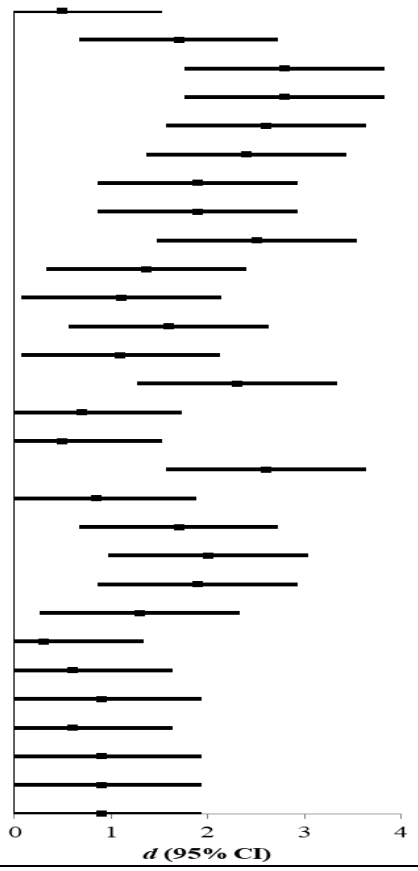
Figure 5. Forest plot for detecting outliers.

Results

To answer the research questions, standard deviations, confidence intervals, and forest plots from the obtained data were executed. The obtained results were organized based on cut-off ages in a descending order. Table 2 presents findings for each individual study as well as a cumulative average effect size with an accompanying forest plot.

TABLE 2
Forest Plot for the Shape of Age Effects (29 samples in SL Context)

Study name	Cut-off ages	*M* (*d*)	Lower limit	Upper limit	Effect size and 95% CI / Forest Plot for *d*
McDonald, 2000	6	0.5	22.6	11.1	
Granena & Long, 2013	7	1.8	8.4	14.4	
Birdsong & Molis, 2001	8	2.8	1.8	5.2	
Johnson & Newport, 1989	8	2.8	1.8	5.2	
Bialystok & Miller, 1999	9	2.6	4.4	11.5	
Bialystok & Miller, 1999	9	2.4	4.0	9.7	
Birdsong & Molis, 2001	11	1.9	2.7	5.2	
Johnson & Newport, 1989	11	1.9	2.7	5.2	
Seol, 2005	11	2.5	1.4	3.6	
DeKeyser et al., 2010	12	1.4	4.6	6.3	
DeKeyser et al., 2010	12	1.1	3.9	4.4	
McDonald, 2000	14	1.6	5.6	2.9	
Abrahamsson, 2012	15	1.1	43.4	47.7	
Patkowski, 1980	15	2.3	10.0	23.1	
Seol, 2005	15	0.7	3.5	2.4	
Ball, 1996	15	0.5	24.9	3.7	
DeKeyser, 2000	15	2.6	6.6	17.3	
Granena & Long, 2013	16	0.8	9.9	8.4	
Granena,_2012	16	1.7	16.6	33.3	
Granena, 2012	16	2.0	17.2	32.7	
Granena, 2012	16	1.9	18.2	31.4	
Johnson & Newport, 1989	17	1.3	3.2	4.3	
Johnson, 1992	17	0.3	3.5	0.8	
Bialystok & Miller, 1999	22	0.6	5.2	3.1	
Bialystok & Miller, 1999	22	0.9	4.0	2.6	
Bialystok & Miller, 1999	23	0.6	2.1	1.9	
Bialystok & Miller, 1999	23	0.9	5.3	8.4	
Seol, 2005	24	0.9	3.4	3.0	
Shim, 1993	24	0.9	3.0	2.6	
Overall		1.13 (.06)	1.0	1.2	



According to Table 2, effects of AO on L2 grammar acquisition continuously decline from age 6 to 24 with an average effect size of d = 1.13, SE = .06. A parallel examination of the AO and effect size in Table 2 disclosed a change in the effect size at age 17. Hence, it was decided to compute separate mean differences from L2 learners who were exposed to L2 before and after this age. The average effect size for the 6-16-year old was quite large d = 1.43, SE = .07, SD = .87 although some fluctuation in the AO effects could be observed for this group. For 17 to 24 years old, a medium effect size was recorded (d = .76, SE = .18, = SD = .29).

Aggregated vs Disaggregated Data

In terms of the shape of age effects, a continuous decline was found for the current set of 29 samples. Figure 6 shows a declining trend (R^2 = .30) for the entire AO range of ages from 6 to 24. However, a gap is witnessed in the data between ages 17 and 22, which indicates a lack of studies covering this age range in the existing research.

Figure 6. Scatter plot: The shape of age effects for 6-24 years old.

To better understand the age function, regression lines were drawn for the 6 to 16 and 17 to 24 years old. For the separate analysis, the age of 17 was chosen based on the data displayed in Figure 6 that showed the remaining studies after this AO exhibited different shape as compared to those before it. Figure 7 shows a trend line for 6 to 16 years.

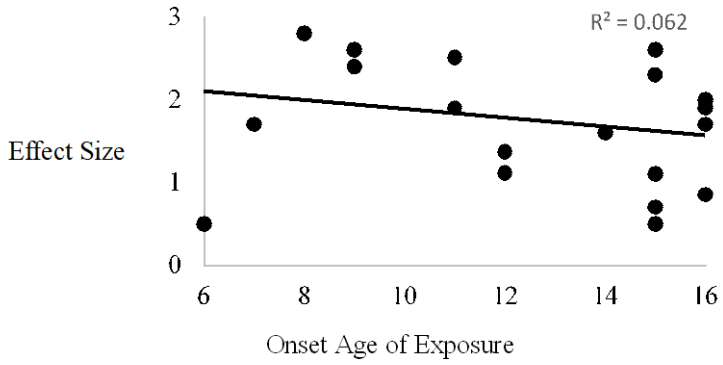


Figure 7. The shape of age effects: 6-16.

Figure 7 displays a decline in grammatical proficiency with an increase in AO for the 6-16-year old groups. The regression line shows a continuous but less steep trend line (R^2 = .08) as compared to the entire range of 6-24 years old. However, the shape of the decline becomes much steeper (R^2 = .32) with the exclusion of the only study with 6 year old participants. The study was retained as it had met the inclusion criteria.

For the remaining 8 samples of 17-24 years old, a flattened line (R^2 = 0) was obtained, which indicates a change in the shape of the declines presented in figures 6 and 7. Results for 17-24 year old are displayed in Figure 8.

Figure 8. The shape of age effects: 17-24.

Based on the current data, if trend lines are drawn using eyeballing method on the entire range of data for the 6-24 years old, two discontinuities might be argued for as displayed in Figure 9.

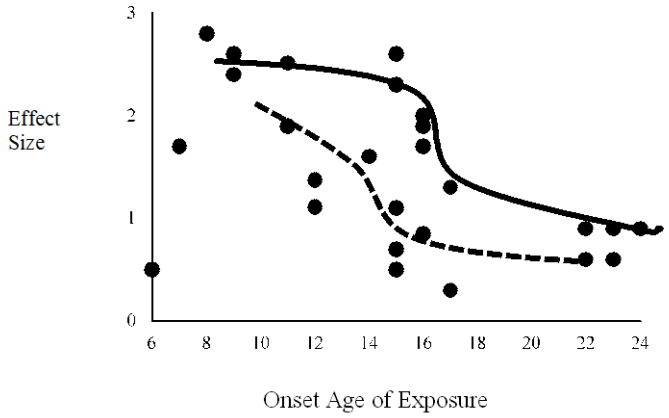


Figure 9. Two shapes of age effects.

Discussion

The current study explored the nature of age effects on L2 grammar acquisition. Findings of this research can be compared with previous claims about the nature of age effects on L2 acquisition. In order to confirm the CPH, it has been argued that the decline in language proficiency should be marked by a discontinuity (DeKeyser, 2012), and the proficiency after the discontinuity should remain relatively constant, without any noticeable decline in language ability (Birdsong, 2006), except for other non-maturational factors (e.g., social, psychological and physiological ones, such as a drop in sensory acuity).

The findings of the current study show a continuous decline, without any discontinuity, for the aggregated data, which might indicate a general decline in language learning ability, contrary to the claims of the CPH. In contrast, the disaggregated data displays a break in language proficiency around AO 16/17 (e.g., Figure 7, 8, & 9). The presence of the discontinuity (e.g., Figure 9) supports a maturational interpretation of the AO effects for language learning. This declining pattern in L2 acquisition supports earlier claims by Johnson and Newport (1989) who observed a non-significant and weak correlation (r = -.16) for the late learners (i.e., those exposed to L2 after 16). This also matches with Long's (2013) claim of the end of the offset of language learning at AO 15 (plus or minus two). Abrahamsson (2012) and Granena and Long (2013) also reported significant negative correlations for learners in < 15 groups, which seems to align with the findings

the current study. Finally, the findings of the current meta-analysis also concur with Hartshorne et al.'s (2018) finding of a critical age of 17 years. They found that human learning ability is well-preserved until the age of 17.4 years; hence, their ability to learn grammar/syntax stays intact as well.

However, based on figure 9, two different shapes of decline as well as three different points for the discontinuity can be witnessed. Line 1 shows a relatively consistent language proficiency until the AO of 15, and then a steep decline onwards till the AO of 17, finally flattening the line onwards until the AO of 24. In contrast, line 2 shows a drop in the proficiency starting around the AO of 12 years that continues until the AO of 15. Onwards from the AO of 15, a leveling off of the AO effects is observed until the age of 24. This validates a reversed pattern of AO effects reported in the comparison between Johnson and Newport (1989) and Birdsong and Molis (2001). A comparison of these with the current study is displayed in figure 10.

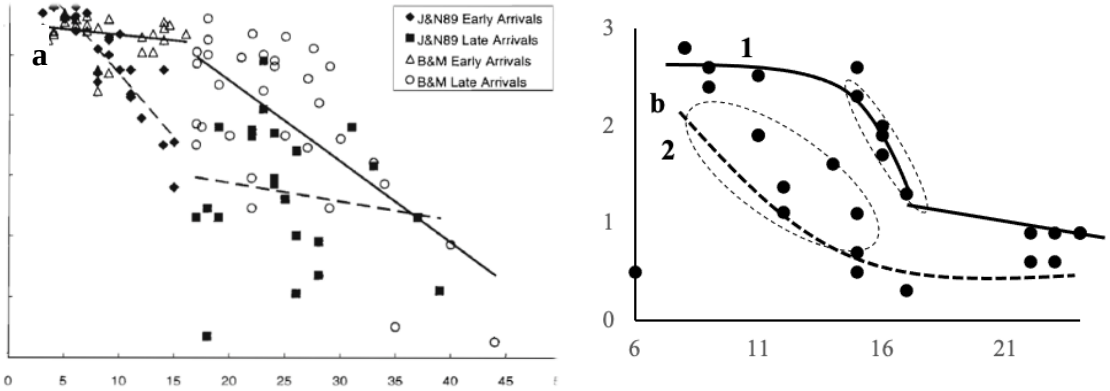


Figure 10. Reversed pattern age in the current study and Johnson and Newport (1989) and Birdsong and Molis (2001).

Johnson and Newport (1989) observed a strong and significant correlation for the early learners (r = -.87) and a weak and non-significant correlation for their late learners. In contrast, Birdsong and Molis (2001) reported a reversed pattern of age effects by detecting a weak and non-significant correlation for the early learners while a strong and significant correlation for the late learners (r = -.67). The current study confirms both configurations, and a closer look at the data reveals L1 backgrounds as a strong moderator. For example, table 3 displays AO effects for 15 to 17 years old, an AO range where the greatest variation exists in findings.

TABLE 3
Age Effects for 15 to 17 Years Old

Study	*L1*	*L2*	*Age*	*d*
DeKeyser_2002	Hungarian	English	15	2.6
Patkowski, 1980	*N* = 67 [24 Spanish L1]	English	15	2.3*
Granena, 2012	Chinese-Spanish bilinguals	Spanish	16	2*
Granena, 2012	Chinese-Spanish bilinguals	Spanish	16	1.9*
Granena, 2012	Chinese-Spanish bilinguals	Spanish	16	1.7*
McDonald, 2000	Spanish	English	14	1.6*
Johnson & Newport, 1989	Chinese/Korean	English	17	1.3
Abrahamsson, 2012	Spanish	Swedish	15	1.1*
Seol, 2005	Korean	English	15	0.7
Ball, 1996	Greek	English	15	0.5
Johnson, 1992	Chinese & Korean	English	17	0.3

According to table 3, six samples in which learners had Spanish as an L1 or were exposed to it before acquiring English (Swedish in one case) as an L2, results indicate relatively larger effect sizes as compared to those studies that had learners with Korean or Chinese as L1s. In these studies, a higher acquisition of proficiency at even an older AO (i.e., 14 to 16) may be attributed to the smaller typological

distance between Spanish and English or Spanish and Swedish as compared to other languages which are more distant from English (e.g., Chinese & Korean). The influence of L1 on the shape of AO effects for L2 morphosyntax is further illustrated in Figure 11.

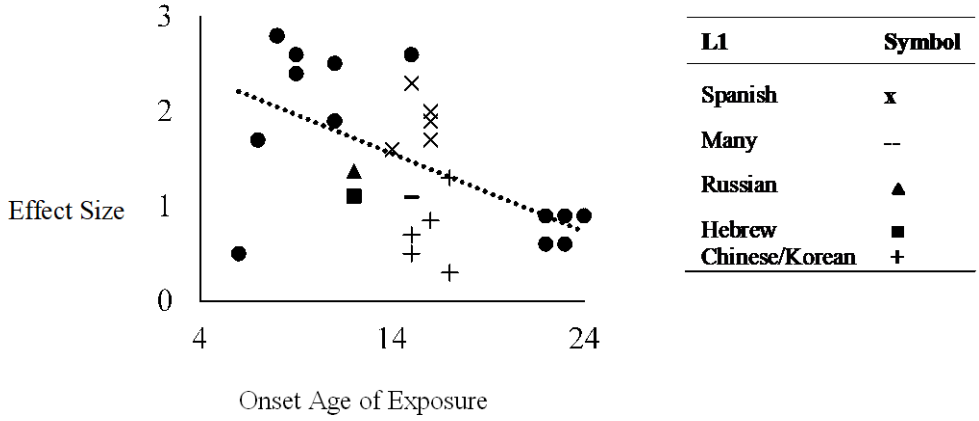


Figure 11. Influence of various L1s on proficiency in L2 morphosyntax for ages 12 to 17.

According to figure 11, participants with L1s that are relatively more distant (i.e., Russian, Hebrew, Chinese, Korean) from English as an L2 appeared to show a greater decline in their ultimate proficiency with increase in the AO. In contrast, learners with Spanish L1, which is typologically closer to English, seems to maintain a relatively higher level of ultimate attainment even in late teens. This pattern of L1 influence on second language acquisition supports the notion of the typological distance between the first and the target language as a probable cause of variance in the ultimate attainment for learners from different L1 backgrounds (see Bialystok & Miller, 1999). Birdsong and Molis (2001) claim that fewer years of exposure to English are required of Spanish speakers as compared to Korean or Chinese speakers. The authors suggest that the smaller typological distances between Spanish and English as compared to Korean/Chinese and English might explain the differential outcome. The current study supports this assertion. Figure 11 shows that L2 learners with Chinese, Korean, Russian, and Hebrew L1s - which are considered more distant from English - have relatively lower effect sizes as compared to learners with Spanish L1, which is typologically closer to English. However, this pattern was not consistently observed for other L1 and L2 pairs. For example, DeKeyser (2000) that involved Hungarian > English L1 and L2 order produced a higher effect size although involving an L1 that is relatively distant from English. In contrast, Ball (1996), which had Greek > English L1/L2 sequence, achieved a low effect size although containing a typologically less distant language combination. Hence, the effects of language distance in relation to AO need further exploration.

Despite the unexplained variations in some L1/L2 pairs discussed above, the findings of the current meta-analysis suggest that the typological distance between the two languages seems to affect the ultimate attainment in an L2. It is interesting to observe that all the studies with Spanish L1 appear to show a relatively sustained ability for acquiring English as a second language, while those with the Chinese/Korean L1s display an early decline. These findings might have policy implications for learning second and foreign languages, both individually as well as in schools, whereby less distant L2 pairings might produce more desired results. Moreover, as the findings of the current meta-analysis are based on a systematic review, with a specific inclusion and exclusion criteria, these render credibility to the outcome of the study, which is also reflected in the fact that the findings here are congruent to the findings reported by other influential studies (e.g., Granena & Long, 2013; Hartshorne et al., 2018; Johnson & Newport, 1989).

Limitations and Future Directions

The results of this meta-analysis suggest a greater scope for further research on AO and L2 acquisition at primary and meta-analytic levels. As the main aim of the current study was to investigate the shape of age effects for L2 grammar acquisition in a naturalistic context, it did not explore the effects of other variables which can potentially influence the outcome, such as the amount of exposure, type of exposure, length of residence, and nature of data collection instruments and procedures. Future research might examine these and other similar variables to extend our understanding of research on AO. Moreover, the current analysis could not explore age effects for learners between 18 and 21 years old, and then beyond 24 because data on these age groups did not exist in the studies that met the inclusion criteria for the current meta-analysis. Future research should include these age groups to extend our understanding of the age effects. It would also be good for future studies to induct participants with different AO (e.g., 4, 5, 6, so on years) to more succinctly analyze the age effects for the discontinuity. Sample size is another aspect that need future attention. In the current study, some groups had only 8 participants. Future studies should include a greater number of participants in each group to ensure that the claims based on them are accurate. Besides, most studies included in the current analysis used some type of GJT, which has uncertain validity (cf. Alanazi, 2015; Bialystok, 1979, Ellis, 1991; Qureshi, 2018, 2020). Future studies should use more diverse and authentic tasks to render validity to the findings based on these instruments.

Conclusion

This study systematically analyzed the shape of age effects for grammar acquisition in L2 contexts. The results of the current meta-analysis are comprehensive and can be generalized as the samples analyzed consisted of participants from 11 different first language backgrounds, acquiring four different second languages. Moreover, learners were organized in 12 different age brackets (i.e., < 6 & > 6; < 8 & > 8) for plotting grammatical proficiency across different ages of exposure. The findings support a maturational explanation for age effects on grammar acquisition. For the shape of age effects, the current analyses reveal two different patterns of decline. The first configuration that involves typologically closer L1s and L2s (e.g., Spanish & English) shows a fairly consistent grammatical ability until the AO of 15, followed by a moderately smoother decline till the AO of 17, and finally leveling off until the AO of 24. The second setup that involves more distant L1s and L2s (e.g., English & Korean) reveals an early decline at AO 12, followed by a second decline at AO 15, finally leveling off until the AO of 24.

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(Received February 25, 2021; Revised May 20, 2021; Accepted June 18, 2021)

