

CONCEPTUAL REVIEW ARTICLE

More Is More in Language Learning: Reconsidering the Less-Is-More Hypothesis

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The Less-Is-More hypothesis was proposed to explain age-of-acquisition effects in first language (L1) and second language (L2) learning. We scrutinize different renditions of the hypothesis by examining how learning outcomes are affected by (a) limited cognitive capacity, (b) reduced interference resulting from less prior knowledge, and (c) simplified language input. While there is little to no evidence of benefits of limited cognitive capacity, there is ample support for a More-Is-More account linking enhanced capacity with better L1 and L2 learning outcomes and reduced capacity with childhood language disorders. Instead, reduced prior knowledge (relative to adults) may afford children greater flexibility in inductive inference; this contradicts the idea that children benefit from a more constrained hypothesis space. Finally, studies of child-directed speech confirm benefits from less complex input at early stages but also emphasize how greater lexical and syntactic complexity of the input confers benefits in L1 attainment.

Keywords less is more; more is more; working memory; cognitive control; processing capacity; individual differences; second language; development

Introduction

There is broad agreement that to acquire language, suitable input needs to be available early in development. In this review, we consider whether children's limited cognitive capacity can provide a viable explanation for such critical period effects. We conclude that direct evidence for the hypothesis that less cognitive capacity supports language learning is lacking. Instead, we argue that with respect to many aspects of cognitive functioning, more capacity is

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beneficial for second (L2) as well as for first language (L1) learning. We also argue that the Less-Is-More hypothesis might be more appropriately applied to children's limited prior knowledge and the reduced complexity of the input typically provided to them, which may explain children's superior outcomes in some (but not all) language learning contexts.

Aside from a few case studies (e.g., Curtiss, 1977), direct evidence for the duration of a critical period for L1 acquisition is difficult to obtain, simply because it is impossible to compare sufficient numbers of individuals with early versus late onset of oral L1 acquisition. Given this limitation, evidence for a critical period relies on two sources of evidence. The first set of findings comes from congenitally deaf individuals deprived of early language input because of lack of access to a sign language and/or societal insistence on oral communication (e.g., Grimshaw, Adelstein, Bryden, & MacKinnon, 1998; Mayberry, Lock, & Kazmi, 2002). Compared to native signers (i.e., hearing or deaf individuals exposed to sign from birth, typically by deaf parents), late signers (i.e., deaf individuals exposed to sign language at school age or later) demonstrate measurable deficits in the quality of their signing over the lifespan: They exhibit difficulties acquiring the complex morphological and grammatical constructions of American Sign Language (ASL), are less sensitive to grammatical errors (Emmorey, Bellugi, Friederici, & Horn, 1995; Mayberry & Eichen, 1991; Newport, 1988), and are also at a disadvantage in acquiring an oral language as a L2 for literacy purposes (Mayberry, 2007; Mayberry & Lock, 2003). Such age-of-acquisition effects are corroborated by studies of congenitally deaf recipients of cochlear implants who fare markedly better when implantation is done at a young age (Connor, Craig, Raudenbush, Heavner, & Zwolan, 2006; Robbins, Koch, Osberger, Zimmerman-Phillips, & Kishon-Rabin, 2004). These findings suggest that for deaf individuals denied usable language input in early childhood, the window of opportunity for acquiring the full complexity of a natural language may well be closed, presumably because the neurophysiological processes involved in establishing pathways for language processing are redirected toward other tasks (Cheng, Halgren, & Mayberry, 2018; Newman, Bavelier, Corina, Jezzard, & Neville, 2002).

The second set of findings that is often taken as support of a critical period for language learning comes from the domain of L2 learning, where later age of first L2 exposure has been linked to deficits in ultimate L2 attainment, summarized by the perhaps too general claim that children are better L2 learners than adults. For example, an influential study involving native Korean and Chinese learners of English demonstrated that accuracy in judging the grammaticality of a wide range of English constructions declined steadily as a function of

learners' age of first L2 exposure up to puberty, even when other experiential and attitudinal variables such as overall years of L2 exposure, amount of classroom instruction, identification with social values of the host country, degree of self-consciousness, and motivation to learn the L2 and to speak it well were taken into account (Johnson & Newport, 1989). Although these and similar studies have been shown to be severely underpowered (Hartshorne, Tenenbaum, & Pinker, 2018; Vanhove, 2013), recent evidence from an extraordinarily large sample exceeding half a million L1 and L2 speakers of English confirmed that ultimate grammatical proficiency declines with age of first L2 exposure, even if the estimated offset of the critical period between 17 and 18 years appears to be much later than previously estimated (Hartshorne et al., 2018).

Traditionally, differences in ultimate L2 attainment as a function of age of first L2 exposure have been attributed to maturational changes that diminish the ability of older learners to acquire a L2 (Lenneberg, 1967; Pakulak & Neville, 2011; Patkowski, 1990; Weber-Fox & Neville, 1996). Yet, maturational explanations need to be reconciled with evidence that cognitive capacity increases with age (Anderson, 2002; Cowan, 2016; Fry & Hale, 2000). To account for this paradox, Newport (1990) offered the hypothesis that age-related increases in cognitive abilities might make language learning more difficult, suggesting that less may be more in language acquisition.

The Less-Is-More Hypothesis

At the heart of this hypothesis is the idea that imposing constraints on the capacity to extract information from language input may benefit learning. Although rarely stated explicitly in the language learning literature, this idea is firmly embedded within an evolutionary approach that views cognitive and social immaturity arising from a prolonged juvenile period in humans as a crucial prerequisite for many aspects of human development (Bjorklund, 2018). With respect to language, researchers have proposed a range of mechanisms linking cognitive constraints to better learning outcomes. Below we briefly describe the various mechanisms that may support the Less-Is-More hypothesis before scrutinizing its empirical basis.

Working Memory Limitations

Newport (1990, 1988) proposed that domain-general capacity limitations might explain why children are more successful at learning languages than adults. Specifically, she suggested that limited working memory capacity restricts children's attention to fewer and smaller chunks comprising shorter linguistic

units, which in turn might facilitate their detecting and analyzing adjacent dependencies and other patterns of linguistic covariation necessary for acquiring morpho-syntactic rules (Goldowsky & Newport, 1993; see also Kareev, 1995; Turkewitz & Kenny, 1982). In contrast, adults with their larger working memory capacity are likely to store larger linguistic units, thereby overlooking variation in morpho-syntactic features or failing to decompose phrases and words into constituent morphemes (but see Arnon & Christiansen, 2017). Under this view, young children's inability to process the full complexity of possible linguistic mappings selectively filters the input, consequently serving to restrict children's hypotheses about form–meaning mappings to the most relevant ones.

Executive Control Limitations

A related account suggests that limitations in cognitive control confer early learning advantages (Chrysikou, Novick, Trueswell, & Thompson-Schill, 2011; Thompson-Schill, Ramscar, & Chrysikou, 2009). Reduced executive functioning limits children's ability to inhibit pre-potent responses and make probabilistic predictions, which renders them liable to regularize unpredictable variation by favoring one particular form–function mapping over others. Adults, on the other hand, are more likely to probability match: Their responses tend to reflect the quantitative distribution of competing form–function mappings in the input. This link between cognitive control limitations and regularization has been invoked as an explanation for the role of children in creolization processes, wherein the grammar of a pidgin becomes more structured over time (Hudson Kam & Newport, 2005, 2009); for example, in Nicaraguan Sign Language, younger cohorts of learners have altered the system by decomposing signs into syntactically motivated spatial morphemes (Senghas & Coppola, 2001; Senghas, Kita, & Özyürek, 2004).

Limitations in Procedural Learning

Another variant of the Less-Is-More hypothesis suggests that age-of-acquisition effects on language learning outcomes are linked to a qualitative developmental shift from implicit, procedural learning to more explicit, attention-driven learning (cf. Karmiloff-Smith, 1992; Ullman, 2001; Zwart, Vissers, Kessels, & Maes, 2017, for models of this trajectory), which may hinder aspects of language learning that involve processing of sequential information. In line with this view, Janacsek, Fiser, and Nemeth (2012) observed an age-related decrement at 12 years in implicit learning of probabilistic sequences of visual-spatial patterns on the Alternating Serial Reaction Time Task

administered to participants ranging in age from 4 to 85 years. In a series of meta-analyses, Hamrick, Lum, and Ullman (2018) found evidence suggesting lesser involvement of procedural memory and greater involvement of declarative memory in adult L2 learners with low levels of L2 experience, in contrast to child L1 learners and adult L2 learners with high levels of experience who show evidence for involvement of procedural memory in grammatical processing. Other recent work has suggested that disrupting prefrontal cortical activity through cathodal transcranial direct current stimulation boosts motor sequence learning (Zhu, Yeung, Poolton, Lee, Leung, & Masters, 2015), which is thought to rely on the same neural substrate as statistical learning of phonological and grammatical information (Ullman, 2001). However, it remains to be seen whether direct benefits from suppression of prefrontal activity can be observed for language learning.

Reliance on Multiword Processing

An alternative proposal is that children are more likely than adults to learn words and syntactic relations from multiword units (Arnon & Christiansen, 2017; Arnon, McCauley, & Christiansen, 2017), either because limited cognitive capacity and lack of conceptual knowledge lead children to undersegment the input or because chunking leads to different learning outcomes in children. Unlike adults, children learn concepts at the same time as they learn grammatical relations, resulting in lexical representations that include co-occurring grammatical morphemes (e.g., in Spanish, gender-marked articles co-occurring with nouns, as in *el libro* [book] or *la mano* [hand]). Overlapping representations of multiword units and their constituent morpho-syntactic components enhance children's ability to make accurate predictions as language unfolds over time. The idea that learning benefits can be derived from larger units is directly at odds with Newport's (1990) original idea that capacity limitations promote learning from smaller units. However, because the process of chunking itself is unlikely to differ for children and adults, this proposal places the origin of age-of-acquisition effects within the realm of learning biases and not capacity limitations.

Empirical Evaluations of the Less-Is-More Hypothesis

The Less-Is-More hypothesis has considerable intuitive appeal due to consensus that processing capacity increases with age, as indicated by developmental studies of working memory, executive functioning, processing speed, and non-verbal intelligence (Anderson, 2002; Cowan, 2016; Fry & Hale, 2000). Yet, for this hypothesis to provide a compelling account of age-of-first-exposure effects

in language learning, it is necessary to demonstrate that children are indeed superior language learners, that disruption of cognitive capabilities supports language learning, and that increased cognitive capacity is associated with reduced learning.

Correlational Studies

In Johnson and Newport's (1989) seminal study, a link between age of exposure and L2 grammaticality judgments was evident only for learners exposed to English (L2) prior to puberty. Learners exposed to English after puberty did not show such a link and exhibited considerable variability in performance. This discontinuity was interpreted as suggesting that once mechanisms required for optimal language learning are no longer accessible after the critical period, language learning is governed by domain-general mechanisms that are susceptible to individual differences in abilities and circumstances. However, other studies have documented more continuous age-of-first-exposure effects on L2 learning that are incompatible with a sharply defined critical period offset around puberty. For instance, in a large-scale study utilizing U.S. census data from 2.3 million immigrants with Spanish or Chinese L1 backgrounds, Hakuta, Bialystok, and Wiley (2003) failed to find evidence of a discontinuity in self-reported English attainment that could be attributed to the offset of a putative critical period. In a replication study using Johnson and Newport's (1989) test materials with Spanish-speaking learners of English, Birdsong and Molis (2001) observed minimal age-of-first-exposure effects in learners exposed to English prior to age 17 and pronounced age-of-first-exposure effects in older learners, perhaps reflecting the influence of confounding factors such as the amount of daily exposure to English versus Spanish, level of education, or motivation to learn English. Given the discrepancy between their results and those of Johnson and Newport (1989), Birdsong and Molis (2001) suggested that the relationship between age of first exposure and L2 learning might vary as a function of L1–L2 pairings as prior language experience modulates the cognitive challenges associated with learning a new language. Even more challenging to the Less-Is-More hypothesis was their observation that some late learners achieve nativelike performance in L2 grammaticality judgments, which demonstrates that cognitive maturity does not create an insurmountable obstacle to L2 learning success.

The existing literature has a range of limitations. First, as indicated above, studies are often severely underpowered, which increases the likelihood that the discrepancies are simply due to statistical noise (Hartshorne et al., 2018; Vanhove, 2013), or based on less reliable self-report data. Second, correlations

between age of first exposure and L2 attainment do not prove the existence of a critical period *per se*, nor do they constitute sufficient evidence for the Less-Is-More hypothesis because age of first exposure is almost always confounded with other factors that conspire to promote L2 acquisition. Individuals with early exposure are likely to receive a much larger amount of L2 exposure over time than individuals with late L2 exposure: They are likely to experience longer periods of formal education in the L2 (Flege, Yeni-Komshian, & Liu, 1999), greater amounts of daily L2 use (Flege, Frieda, & Nozawa, 1997; Flege, Munro, & MacKay, 1995), a higher degree of literacy in the L2 (Elley & Mangubhai, 1983; Jia & Aaronson, 2003), and stronger motivation to conform linguistically with peers (Jia & Aaronson, 2003). Furthermore, age of L2 exposure tends to correlate with dominance of and amount of experience with the L1, which may result in greater interference from the L1 in late L2 learners. Indeed, Flege et al. (1995) observed greater L1 (Italian) accent as a function of age of L2 exposure to English—a pattern similar to the findings for grammaticality judgments described above. At the same time, L1 use predicted the degree of accent over and above the effect of age of first exposure. Although infrequently emphasized, early L2 exposure is often accompanied by L1 attrition, with some individuals undergoing a dominance shift and potentially losing their L1 skills (Fillmore, 1991; Jia & Aaronson, 2003; but see Schmid, 2007). Indeed, children growing up in bilingual households in the United States often do not acquire proficiency in both languages. Frequently, such children have only passive knowledge of their heritage language while attaining full command of English. Recent longitudinal work in bilingual Spanish–English communities of South Florida has indicated trade-offs between children’s usage of English and their ability to speak Spanish as a heritage language (Hoff & Ribot, 2017). Factors such as the presence of school-age siblings and the tendency to engage in conversational code switching (e.g., using English to answer questions posed in Spanish) impede acquisition of Spanish, despite substantial daily exposure to the language from birth (Ribot, Hoff, & Burrridge, 2018). Thus, substantial evidence suggests that the link between age of L2 exposure and ultimate attainment may arise from a host of factors unrelated to gains in cognitive capacity (Hartshorne et al., 2018; Mayberry & Kluender, 2017).

Quasi-Experimental Studies

Acknowledging that the presence of confounding factors necessitates moving beyond correlations, researchers have tested the Less-Is-More hypothesis using quasi-experimental designs that compare performance of adults and children on language learning tasks. The main prediction is that children should

demonstrate superior overall learning or at least exhibit some qualitative aspects of learning that are considered advantageous for learning linguistic structure, like regularization of unpredictable variation or decomposition of complex constructions.

In a series of studies utilizing artificial languages, Hudson Kam and Newport (2005, 2009) compared children and adults learning artificial languages where the distribution of determiners followed a consistent or inconsistent pattern in the input. Children regularized inconsistent input by using one determiner at the expense of others (Hudson Kam & Newport, 2005). Adults, in contrast, only regularized input with very complex patterns of inconsistency (Hudson Kam & Newport, 2009). Such findings were taken as support for the view that children play a crucial role in systematizing and regularizing inconsistent language input as it is transmitted over generations. However, Perfors (2012a, 2016) showed that when adults experienced less pressure to be correct, they regularized the input just as much as children—leaving open the possibility that the observed differences between adults and children in regularization may be due to differences in pragmatic and social assumptions about the goals of the task and the nature of the encountered variation, rather than cognitive limitations.

Experimental Studies

To avoid confounding factors that differentially affect performance of children versus adults in quasi-experimental studies, researchers have scrutinized the Less-Is-More hypothesis through direct experimental manipulations of cognitive capacity. Thus, to test the prediction that limiting working memory capacity facilitates learning of form–meaning mappings, Cochran, MacDonald, and Parault (1999) taught modified ASL signs to naïve adults while manipulating concurrent load (i.e., requiring participants to count tones while attempting to learn signs) and compared their performance to a no-load control group. Although the no-load group exhibited faster learning of the signs, they tended to make holistic errors in a generalization test by producing signs exactly as they were learned rather than adjusting them to fit new contexts. Participants in the load condition made few holistic errors but omitted individual components of signs and showed worse performance overall. In another experiment, Cochran et al. (1999) had participants practice whole signs or parts of signs. Participants who practiced whole signs tended to produce holistic errors, which suggested that they failed to decompose the signs into constituent morphemes, as predicted by the Less-Is-More hypothesis. Note, however, that Rohde and Plaut (2003) heavily critiqued this study as providing little evidence that cognitive

load facilitates decomposition of signs into morphemes, instead emphasizing the noisy and overall poor performance of the load group relative to the no-load group.

Another manipulation of cognitive resources involves boosting cognitive capacity by making tasks easier. Hudson Kam and Chang (2009) showed that the amount of regularization decreased when learners were given flashcards with words printed on them to reduce demands on lexical retrieval. Yet, conversely, manipulations designed to increase cognitive load did not increase regularization: When Perfors (2012b) tested adults under six different load conditions as they learned an artificial language with complex patterns of inconsistency (modeled after Hudson Kam & Newport, 2009), load groups were no more likely to regularize determiner use than a no-load control group. Indeed, the data showed a nonsignificant trend in the opposite direction, with less regularization under concurrent load, counter to predictions of the Less-Is-More hypothesis.

Computational Evidence

Although numerous computational models have successfully simulated language learning trajectories (Freudenthal, Pine, Aguado-Orea, & Gobet, 2007; Mintz, 2003; Redington, Chater, & Finch, 1998), only a few have manipulated processing capacity directly. In a seminal study, Elman (1993) trained a recurrent neural network to learn a semi-artificial language consisting of sentences with verbs in various grammatical constructions. The sentences differed in complexity in that they could contain zero, one, or multiple embedded units (e.g., relative clauses). The network was trained to predict the next word in the sentence, a task that required knowledge of the underlying grammar. While learning outcomes were unsatisfactory when the network was trained on the full corpus of sentences, grammar learning was more successful when two types of changes were independently introduced: an incremental input manipulation (discussed below) and a capacity manipulation, which was accomplished by gradually increasing the number of words that were held in memory through the recurrent feedback connections or by gradually enlarging the initially small network. Elman's models were taken as evidence that simplified input or capacity limitations can lead to superior learning outcomes.

However, subsequent attempts to replicate the benefit of starting small cast doubt on the generality of Elman's computational account of the Less-Is-More hypothesis. After failing to replicate Elman's modeling results, Rohde and Plaut (1999) outlined problems associated with pretraining recurrent neural networks on only some types of form–meaning mappings or on some local dependencies.

In such cases, the network may show effects of catastrophic interference where patterns of connectivity among hidden units become entrenched during learning, hindering subsequent learning that requires establishing a different pattern of connectivity. Further doubt about the benefits of capacity limitations comes from statistical models: Perfors (2012b) explored effects of capacity limitations by simulating learning as a process of Bayesian inference. She demonstrated that when capacity is diminished, regularization takes place only if an a priori bias toward regularization is present, which suggests that regularization is not a result of capacity limitations *per se*.

In sum, despite its intuitive appeal, the empirical evidence for the Less-Is-More hypothesis with respect to various aspects of cognitive capacity is weak: Correlational studies suggest continuous age-of-exposure effects that either extend over the lifespan or suggest an offset of the critical period at a time later than when cognitive capacity is fully established. They also leave open the possibility that other individual and situational factors can shape task demands and learning trajectories in different ways for children and adults. At the same time, experimental and computational evidence for regularization and decomposition arising from direct manipulations of working memory capacity and cognitive control remains equivocal. Moreover, it stands to reason that regularization and decomposition, rather than being beneficial, may in fact be detrimental for language learning, especially for complex morphological systems. For example, in Russian singular nouns, markers for six cases vary according to three declension paradigms comprising feminine nouns ending in /-a/ or /-ya/ in the nominative, masculine, and neuter nouns, and feminine nouns ending in palatalized consonants in the nominative. At the same time, adjectives and past-tense verbs must agree with the grammatical gender of their referents (masculine, feminine, or neuter). This complexity appears unpredictable at the outset of learning until sufficient information from the relevant probabilistic co-occurrence patterns of the various gender and case cues has been accrued. If children were prone to regularize the system by relying on the use of one declension paradigm or one gender agreement pattern at the expense of the others, it would impede acquisition of the underlying declension system (Kempe & Brooks, 2014). Yet, empirical evidence suggests that children readily acquire many aspects of these complex systems as early as 3 years of age (Kempe, Brooks, Mironova, & Fedorova, 2003).

Children's increased propensity for decomposition and regularization has been assumed to shape emergence of language structure, for example, when children are credited with introducing syntactically motivated spatial morphemes into a newly emerging language like Nicaraguan Sign Language

(Senghas & Coppola, 2001; Senghas et al., 2004). How can this assumption be reconciled with the paucity of empirical support for a link between children's capacity limitations and increased regularization and decomposition? Insights may come from iterated language learning studies, which are taken as laboratory simulations of changes that occur during language transmission. Such studies demonstrate that creation of arbitrary, compositional signs is exactly what would be expected if a signaling system, such as an emerging sign language, were transmitted by successive generations of users. Kirby, Tamariz, Cornish, and Smith (2015) showed that compositional grammatical structure, which entails systematically linking elements of the form with dimensions of meaning, emerges when signaling systems are subjected to the dual pressures of having to be learnable and communicatively expressive. As these two conditions are met in the context of creating a new sign language, subsequent generations of learners of an initially holistic and idiosyncratic communication system would be expected to introduce compositional grammatical structure, regardless of their age. Hence, in the case of Nicaraguan Sign Language, although the subsequent learners happened to be children, there is no evidence that it was their cognitive immaturity rather than their position in the transmission chain that led to their decomposing and regularizing the signs.

The More-Is-More Hypothesis

In contrast to the paucity of evidence in support of the Less-Is-More hypothesis, there has been intensive investigation of individual differences in processing capacity in relation to L1 and L2 learning outcomes that support a More-Is-More account. Here research has attempted to link individual differences in language learning with several interacting components of capacity, including phonological short-term memory, working memory, and executive functioning (Kidd, Donnelly, & Christiansen, 2018).

Predicting L1 Learning Outcomes

Many studies investigating individual differences in language learning have focused on phonological short-term memory capacity, often assessed via nonword repetition tasks that require individuals to repeat back nonsense words of varying lengths (Gathercole, Willis, Baddeley, & Emslie, 1994). In an early study of word learning in 5-year-olds, Gathercole and Baddeley (1990) observed that children with high nonword repetition ability outperformed their peers in learning names of unfamiliar toys. Using a longitudinal design to determine the direction of the relationship, Gathercole Willis, Emslie, and Baddeley (1992) found significant cross-lagged correlations between nonword repetition and L1

vocabulary size of children tested on three occasions between 4 and 8 years of age, with nonword repetition scores at earlier time points predicting vocabulary size at later time points. Gathercole, Hitch, Service, and Martin (1997) further demonstrated a significant relationship between nonword repetition and word learning in 5-year-olds after controlling for nonverbal ability and vocabulary size, which led them to conclude that the phonological loop (i.e., storage capacity) might serve as a language learning device (Baddeley, Gathercole, & Papagno, 1998). However, subsequent replications with sizeable samples have suggested that the relationship may be reversed, that is, having a larger vocabulary may enhance short-term storage of linguistic information (Melby-Lervåg, Lervåg, Lyster, Klem, Hagtvet, & Hulme, 2012). While the direction of causality is under debate (MacDonald, 2016), the relationship between memory measures (such as nonword or sentence repetition) and language skills (such as vocabulary) is a positive one (Klem, Melby-Lervåg, Hagtvet, Lyster, Gustafsson, & Hulme, 2015). Indeed, children with Developmental Language Disorder (also known as Specific Language Impairment) exhibit deficits to such an extent that nonword repetition (Bishop, North, & Donlan, 1996; Estes, Evans, & Else-Quest, 2007), sentence repetition (Conti-Ramsden, Botting, & Faragher, 2001), and sentence recall (Archibald & Joanisse, 2009) are viewed as useful behavioral markers for the disorder. Extending findings beyond L1 acquisition, there is considerable evidence that verbal working memory capacity correlates with L1 comprehension throughout the lifespan—see Daneman and Merikle (1996) for a meta-analysis of sentence-processing studies and Carretti, Borella, Cornoldi, and De Beni (2009) for a meta-analysis of studies testing individuals with impaired reading comprehension.

Notably, the link between cognitive capacity and language skills in children extends beyond verbal measures, as meta-analytic reviews involving large numbers of studies and participants implicate deficits in nonverbal processing capacity in the etiology of Developmental Language Disorder. These include deficits in sustained attention (Ebert & Kohnert, 2011), visual-spatial working memory (Vugs, Cuperus, Hendriks, & Verhoeven, 2013), procedural learning (Lum, Conti-Ramsden, Morgan, & Ullman, 2014), cognitive control and executive functioning (Pauls & Archibald, 2016), and nonverbal intelligence (Gallinat & Spaulding, 2014). Such relationships are evident in children at risk of language delays, as in a recent study of children from low-income families constituting the no-treatment group of the Early Head Start Research and Evaluation Project (Brooks, Flynn, & Ober, 2018), where individual differences in infants' sustained attention at age 14 months predicted vocabulary size at age 36 months after controlling for other significant variables.

Predicting L2 Learning Outcomes

Consistent with findings from L1 acquisition, studies of L2 acquisition provide support for the More-Is-More account. In an early study involving Finnish schoolchildren, Service (1992) observed that students' ability to repeat back English-sounding nonwords at age 9 predicted their English proficiency at age 11. Likewise, in a study of 12-year-old Chinese students learning English as a L2, Cheung (1996) reported a significant correlation between nonword span (i.e., the maximum length of a sequence of two-syllable nonwords that could be repeated back correctly) and the number of trials required to learn English words. Extending the work to adults, Papagno, Valentine, and Baddeley (1991) and Ellis and Sinclair (1996) demonstrated that engaging participants in articulatory suppression (e.g., requiring them to count from one to five in a continuous cycle) interfered with L2 learning, presumably by disrupting short-term memory storage. Note that this finding is in direct contradiction to predictions from the Less-Is-More hypothesis. Moreover, Ellis and Beaton (1993) observed that techniques like rote rehearsal and imitation that help adult learners to maintain novel words in short-term memory facilitated L2 learning. Likewise, nonword repetition and phonological sequence learning have been shown to correlate with individual differences in L2 vocabulary acquisition (Speciale, Ellis, & Bywater, 2004).

Other studies have linked verbal working memory capacity with L2 sentence processing; see Linck, Osthus, Koeth, and Bunting (2014) for a meta-analytic review. In a study of Japanese learners of English, Miyake and Friedman (1998) linked verbal working memory capacity with L2 comprehension specifically in regard to using word order and subject–verb agreement as cues to grammatical roles. Similarly, using a miniature artificial language, Ellis and Schmidt (1997) found learners' ability to maintain verbal information in memory to predict their accuracy in grammaticality judgments for sentences with long-distance dependencies (subject–verb agreement for transitive sentences with subject-object-verb word order). Other studies of individual differences in L2 learning have included measures of nonverbal intelligence and auditory sequence learning as indices of processing capacity (Andringa, Olsthoorn, van Beuningen, Schoonen, & Hulstijn, 2012; Brooks & Kempe, 2013; Brooks, Kwoka, & Kempe, 2017; Granena, 2013; Kempe & Brooks, 2011); these studies collectively provide support for the view that processing capacity may be a fundamental component of language learning aptitude (Grigorenko, Sternberg, & Ehrman, 2000; Linck et al., 2013).

The More-Is-More hypothesis that individuals with greater cognitive capacity are better language learners leads to the prediction that when input and

learning conditions are similar, adults should learn more efficiently than children, and older children should learn more efficiently than younger children. This prediction is supported by a number of studies. Snow and Hoefnagel-Höhle (1978) compared native English speakers, ranging in age from 3 years to adulthood, in their learning of Dutch, using measures of pronunciation, auditory discrimination, morphology, sentence repetition, translation, vocabulary knowledge, comprehension, and production fluency. In all tests except pronunciation, younger children performed worst and adolescents performed best, closely followed by adults. d'Ydewalle and Van de Poel (1999) investigated incidental L2 learning from subtitled television programs and found no learning benefits for children compared to adults. Using an artificial language, Braine et al. (1990) demonstrated that when learners were exposed to exactly the same amount of input, adults outperformed children in acquiring grammatical gender and case marking (see also Brooks, Braine, Catalano, Brody, & Sudhalter, 1993). Similarly, Saffran (2001) observed adults outperforming children in registering statistical regularities associated with word classes and phrase structure rules. This and other studies showing a slower rate of L2 learning in children than adults (e.g., Krashen, Scarcella, & Long, 1982) led Saffran to suggest that due to their limited processing capacity, children might need more input than adults to register statistical regularities or that phrase structure rules might not be subject to critical period effects. We would argue that the more parsimonious interpretation is that learners with greater capacity are at an advantage in acquiring many aspects of language.

Less-Is-More Redux: Less Knowledge Allows Children to Consider a Broader Range of Hypotheses

While the evidence for beneficial effects of processing limitations on language learning is unconvincing, different learning outcomes may arise from differences between children's and adults' prior knowledge. In contrast to Newport's hypothesis that limited processing capacity restricts hypothesis space, thus giving young children access to fewer potential rules, Gopnik, Griffiths, and Lewis (2015) proposed that limited prior knowledge allows children to entertain a more open-ended and less constrained set of hypotheses. For learning in non-linguistic domains, this idea has been supported in studies involving a "blicket" detector, where participants had to determine which settings made an unknown object introduced as "blicket" emit sounds (Griffiths, Sobel, Tenenbaum, & Gopnik, 2011; Lucas, Bridgers, Griffiths, & Gopnik, 2014): in these studies children were more likely than adults to grasp complex causal rules that adults may have overlooked because of prior knowledge and experience biasing their

hypotheses. Relatedly, Ellis (2002) has suggested that the progressive tuning of attention over the course of language learning may decrease sensitivity to other possible patterns of variation—a mechanism that has also been invoked to explain the perceptual magnet effect in speech perception (Kuhl & Iverson, 1995).

McDonough, Choi, and Mandler (2003) explored how categorization biases change with development and whether infants are indeed more flexible learners than adults. In oddity detection/preferential looking tasks requiring participants to categorize exemplars of contrasting spatial concepts, English-speaking adults and infants were successful in distinguishing scenes depicting the familiar English lexical contrast between “*in*” for containment (e.g., “corks plugged into bottles”) versus “*on*” for support (e.g., “foam letters placed standing up on a surface”). However, when presented with scenes depicting spatial relations that exemplified the unfamiliar Korean lexical contrast between tight-fit “*kkita*” (e.g., “keys inserted into tight-fitting keyholes”) versus loose-fit “*nohta*” (e.g., “blocks placed into a loose-fitting sack”), infants from English-speaking homes, infants from Korean-speaking homes, and Korean adults all showed a strong preference to select the exemplar of the familiar concept at test whereas English-speaking adults performed at chance due to interference from their preexisting knowledge of English spatial terms. Infants, unlike adults, were flexible in carving out spatial categories that matched either the English or Korean lexicalization patterns.

Other research has emphasized how prior learning enhances subsequent processing through mechanisms such as priming. Even at early stages of L1 acquisition, infants exhibit learning trajectories that obey power-law functions indicative of the beneficial effect of practice (Ninio, 2006). Similarly, in L2 learning and in literacy acquisition, growth trajectories reflect the benefits of prior learning in improving the accuracy of predictions and facilitating subsequent learning, with advantages of more efficient processing accumulating over time (Ellis, 2012; Stanovich, 1986). As learners develop facility in processing information in a given domain, their hypotheses become more constrained, which can contribute to L1–L2 transfer but also to interference that can hinder L2 learning (Ellis, 2002; McDonough et al., 2003).

Less-Is-More Redux Again: Less Complex Input Benefits Language Learning

In his neural network simulations of the Less-Is-More hypothesis, Elman (1993) also explored whether scaffolded, simplified input might be beneficial at early stages of learning. Although input manipulations, which involved exposing the network to a subset of form–meaning mappings before expanding the input to

encompass the full range of mappings, are not comparable to input restrictions that arise from children's memory limitations (Rohde & Plaut, 1999), it is worth considering whether reducing the complexity of the input facilitates language learning.

Direct tests of this formulation of the Less-Is-More hypothesis come from experimental studies that manipulated the complexity of input at different stages of learning, with the purpose of determining whether simpler input at the outset facilitates subsequent processing of more complex input. In Kersten and Earles (2001), naïve adults attempted to learn a miniature artificial language consisting of trisyllabic words combined into three-word sentences. In the incremental input group, the first block of training consisted of one-word sentences, the second block of two-word sentences, and the final block of three-word sentences whereas the control group received three-word sentences from the outset. Across a set of experiments, the incremental input group showed superior learning, suggesting that reducing the complexity of the input at early stages was advantageous for learning vocabulary and grammatical morphology (see also Conway, Ellefson, & Christiansen, 2003).

Evaluating this version of the Less-Is-More hypothesis requires examining what the input is actually like for children and whether it bears resemblance to the input manipulations used in the above-mentioned experimental studies. There is considerable evidence that child-directed speech (CDS) registers, although variable across languages and cultures, tend to be characterized by a number of specific features: Prosodic patterns are exaggerated; sentences and clauses are shorter; vocabulary is more repetitive; and novel words tend to occur in salient positions, such as at the end of utterances (Soderstrom, 2007). Moreover, in CDS, a substantial number of words are produced in isolation, which may help children identify word boundaries, detect statistical regularities in the input, and learn word meanings (Brent & Siskind, 2001; Lew-Williams, Pelucchi, & Saffran, 2011; Ninio, 2016). Infants are differentially responsive to CDS and prefer to listen to it (Cooper & Aslin, 1990; Fernald, 1985; Werker, Pegg, & McLeod, 1994). Ma, Golinkoff, Houston, and Hirsh-Pasek (2011) observed that 21-month-olds learned words more readily from CDS than from adult-directed speech (ADS), although by age 27 months toddlers learned just as readily from ADS.

Other aspects of CDS have been shown to facilitate learning. For instance, children appear to benefit from the use of diminutives suffixes, a derivation which mainly serves an affective function, yet in some languages creates clusters of nouns with similar morpho-phonological properties, rendering grammatical categories (e.g., gender or case) more transparent and easier to learn

(Savickienė, Kempe, & Brooks, 2009; Ševa et al., 2007). More generally, children benefit when CDS builds on what they have already said or have in mind (Che, Brooks, Alarcon, Yannaco, & Donnelly, 2018; Tamis-LeMonda, Bornstein, & Baumwell, 2001); such input may be impactful because it is specifically tailored to their limited attention spans.

Several studies have explored whether features of CDS might be beneficial for L2 learning. For example, placing target words in salient utterance-final position, as is typical for CDS, has been shown to enhance learning of Chinese vocabulary (Golinkoff & Alioto, 1995). Likewise, providing frequent diminutives in the input may facilitate learning of Russian morphology (Brooks, Kempe, & Donachie, 2011; Kempe & Brooks, 2001) and word segmentation (Kempe, Brooks, & Gillis, 2005).

However, even in the context of CDS, there is evidence favoring a More-Is-More account. In assessing the impact of variable input on language outcomes, a large body of work has compared children of varying socioeconomic backgrounds where disparities have been described as a “30 million word gap” in input directed toward low-income children (Hart & Risley, 2003; Hoff, 2003). Research findings emphasize the importance of higher-quality input, exemplifying a more diverse range of vocabulary and grammatical constructions, in facilitating language growth (Huttenlocher, Vasilyeva, Cymerman, & Levine, 2002; Pan, Rowe, Singer, & Snow, 2005; Rowe, 2012), and the benefits of shared book reading and other activities that elicit more complex speech (Raikes et al., 2006; Weigel, Martin, & Bennett, 2006). Extending the work to adults, Dąbrowska and Street (2006; Street & Dąbrowska, 2010) have similarly linked socioeconomic variability in L1 attainment with input-related factors. Thus, while less complex input may facilitate language learning in infancy, subsequent growth requires gradual expansion in the complexity of CDS, commensurate with learners’ needs and abilities.

Conclusion

Various conceptualizations of the original idea that limited processing capacity helps children to acquire the complexities of human languages and may explain their putative superiority in L2 learning have received little direct empirical support. Instead, the literature provides considerable evidence favoring a More-Is-More account where increased cognitive capacity facilitates L1 and L2 acquisition, while indicating that lesser capacity is a risk factor for Developmental Language Disorder. Counter to the view that limited capacity filters the input and thus serves to constrain hypotheses, children’s limited knowledge may minimize interference from prior biases, allowing younger L2 learners

to entertain a broader range of hypotheses than older L2 learners. Finally, we explored whether simplification of the input might aid language learning and found evidence of benefits from some specific features of CDS. At the same time, research on individual differences suggests that, as learning progresses, the lexical and grammatical complexity of input needs to increase appropriately to accelerate further language learning. We therefore conclude that immature cognitive processing capacity, a constrained hypothesis space, and reduced input complexity are not suitable explanations for the link between age of exposure and individual differences in language attainment.

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