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Gullberg, Marianne, Roberts, Leah orcid.org/0000-0002-5666-6667, Dimroth, Christine et al. (2 more authors) (2010) *Adult Language Learning After Minimal Exposure to an Unknown Natural Language*. *Language Learning*. pp. 5-24. ISSN 0023-8333

<https://doi.org/10.1111/j.1467-9922.2010.00598.x>


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	LANG	lang_598	Dispatch: 9-4-2010	CE: N/A
	Journal	MSP No.	No. of pages: 20	PE: Matthew

Language Learning ISSN 0023-8333

# Adult Language Learning After Minimal Exposure to an Unknown Natural Language

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Despite the literature on the role of input in adult second-language (L2) acquisition and on artificial and statistical language learning, surprisingly little is known about how adults break into a new language in the wild. This article reports on a series of behavioral and neuroimaging studies that examine what linguistic information adults can extract from naturalistic but controlled audiovisual input in an unknown and typologically distant L2 after minimal exposure (7–14 min) without instruction or training. We tested the stepwise development of segmental, phonotactic, and lexical knowledge in Dutch

We gratefully acknowledge support from the Max Planck Institute for Psycholinguistics and funding from the Nederlandse Organisatie voor Wetenschappelijk Onderzoek, NWO, MPI 56-384, The Dynamics of Multilingual Processing, awarded to M. Gullberg, P. Indefrey, and W. Klein. We also thank Kim Veroude, Aoju Chen, Jidong Chen, Rosa Zhang, Arna van Doorn, Nanna Haug Hilton, Wilma Jongejan, Gerrit-Jan Kootstra, and Linda van Meel.

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1 Gullberg et al. Adult Learning After Minimal Exposure to Natural Language

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3 adults after minimal exposure to Mandarin Chinese and the role of item frequency,  
4 speech-associated gestures, and word length at the earliest stages of learning. In an  
5 exploratory neural connectivity study we further examined the neural correlates of word  
6 recognition in a new language, identifying brain regions whose connectivity was related  
7 to performance both before and after learning. While emphasizing the complexity of the  
8 learning task, the results suggest that the adult learning mechanism is more powerful  
9 than is normally assumed when faced with small amounts of complex, continuous  
10 audiovisual language input.

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Far too little empirical attention has been paid  
to the very beginnings of the acquisition process

Perdue, 1996, p. 138

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It is a challenging task to learn a new, second language (L2) as an adult outside  
a classroom and without any help or instruction. Under such circumstances,  
learners must rely entirely on their own capacities for dealing with the language  
input to which they are exposed. The success of such learning depends on  
the kinds of prior linguistic and nonlinguistic knowledge that learners bring  
to the task and on the structure of the input. The process of breaking into  
a new language, what Klein (1986, p. 59) called the learner's "problem of  
analysis," consists of at least three elements: the segmentation of the continuous  
speech stream to identify relevant strings such as words; the identification of  
relevant meaning in the environment that can be mapped onto the sound strings  
identified; and, finally, the generalization beyond exemplars in the input to  
novel items and the formation of linguistic categories and regularities ("rules").  
Despite the considerable literature on adult L2 acquisition, surprisingly little is  
known about how adult untutored L2 learners go about this complex task "in  
the wild."

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The L2 literature has long debated the role of input for learning and what  
adult learners are able to do with the information available in the linguistic in-  
put (see Carroll, 1999, 2001, 2004, for discussions of this notion). The debate  
is partly prompted by the observation that adult learners do not replicate the  
information in the input very well and therefore do not seem to use the avail-  
able information efficiently. Consequently, a wealth of research has examined  
possible differences between input and intake (e.g., Schmidt, 1990), the role  
of attention and noticing (e.g., Gass, Svetics, & Lemelin, 2003; Izumi, 2002;  
Robinson, 2003; Schmidt, 2001; Wong, 2001), differences between explicit  
versus implicit learning, and declarative versus procedural knowledge (e.g.,

1 Gullberg et al. Adult Learning After Minimal Exposure to Natural Language

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3 Anderson, 1976; DeKeyser, 2003; Ellis, 1994; Hulstijn, 2003; Paradis, 2009;  
4 Ullman, 2001), an so forth.

5 Interestingly, the theorizing about what the adult L2 learner is or is not  
6 capable of both in terms of developing representations and processing typically  
7 draws on data from stages of learning during which a considerable amount  
8 of knowledge has already been acquired (this is true even for studies explic-  
9 itly concerned with “the initial state” of L2 acquisition; see, e.g., articles in  
10 Schwartz and Eubank, 1996); that is, theories generally consider learners who  
11 already have vocabularies and grammatical systems available to bootstrap the  
12 learning of more material in the L2. With a few notable exceptions (e.g., Klein  
13 & Dimroth, 2009), most theories of the capacity of the adult learning mech-  
14 anism are based on intermediate learning stages during which knowledge has  
15 been acquired that can boost further input processing. This is all the more sur-  
16 prising because the conclusions that can be drawn from language acquisition  
17 research about native and nonnative speech processing and about the nature  
18 of learning itself are dependent on how we see the interaction between the  
19 language faculty (which kind of knowledge is relevant, etc.) and the structure  
20 of the language input with which it has to deal. “[T]he topic remains one of the  
21 most under-theorized and under-researched areas of our field” (Carroll, 1999,  
22 p. 338).

Q1 change to reference

23 To gauge the limitations and capacities of the adult language learning mech-  
24 anism, it is important to capture it at work at first contact and after minimal  
25 exposure to the new language—that is, to control the effects of preexisting  
26 (linguistic) knowledge in order to minimize the effects of previously learned  
27 languages (cf. research on crosslinguistic influence in the L2; e.g., Jarvis &  
28 Pavlenko, 2008). Moreover, to understand which auditory and/or visual fea-  
29 tures in the input are noticed, attended to, and taken as evidence of linguistic  
30 distinctions by learners, it is important to control the incoming string and  
31 its properties. Studies of artificial language learning (e.g., see this ~~issue~~) do  
32 precisely that, but often from a different perspective than L2 studies.

volume 

33 The aim of the studies summarized here has been to achieve these goals  
34 while simulating the complexity of the learning task in the wild by exposing  
35 adult learners to natural language in an audiovisual (but noninteractive) setting,  
36 controlling preexisting linguistic knowledge, and controlling the properties  
37 of the input language. Inspired by an unpublished pilot project conducted at  
38 the Max Planck Institute for Psycholinguistics (Zwitzerlood et al., 1994), we  
39 have developed and successfully used a test paradigm allowing us to examine  
40 the earliest perception and processing of input in an unknown natural L2 and  
41 the stepwise development of segmental, lexical, and phonotactic knowledge of

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1 Gullberg et al. Adult Learning After Minimal Exposure to Natural Language

2  
3 a new language. We have probed the development both at the behavioral and  
4 at the neurological level to examine the capacity to isolate strings or identify  
5 forms in the input, to identify relevant meaning from the context and map it  
6 onto new sound strings or word forms, and to generalize beyond the input and  
7 extract more abstract information such as phonotactic knowledge.

8 This series of studies differs from related research in its focus on natural,  
9 complex, and continuous audiovisual input rather than artificial auditory or  
10 written input, in its emphasis on implicit learning outside a classroom context,  
11 and in the absence of training. We also examine the effects of minutes rather than  
12 hours or weeks of exposure. Moreover, in contrast to many studies examining  
13 the role of frequency in processing and language learning (for an overview  
14 of L2 effects, see Ellis, 2002), we investigate the effect of item frequency at  
15 very low limits of frequency. Finally, we target broader contextual cues like  
16 speech-associated gestures accompanying speech.

### 17 18 19 **The Input: A Weather Report in Mandarin Chinese**

20  
21 The aim was to test adult learners' capacity to extract linguistic knowledge from  
22 textually coherent linguistic input in a natural but unknown language without  
23 help while (a) controlling for and minimizing the influence of preexisting  
24 linguistic knowledge, keeping knowledge of known languages constant and  
25 knowledge of the target language to zero, and (b) controlling for frequency  
26 of a set of target words and for "highlighting" of target words in the form of  
27 accompanying gestures.

28 To that end, we constructed 7 minutes of controlled but naturalistic input  
29 in the form of a weather report in Mandarin Chinese, a language typologically  
30 and genetically unrelated to the participants' native language (Dutch) or any  
31 language known to them. The weather report consisted of 120 clauses of co-  
32 herent text containing one out of a set of target word per clause (for details,  
33 see Gullberg, Roberts, & Dimroth, in press). The target words were distributed  
34 across the clauses to appear in clause-initial, medial, or final position to avoid  
35 position effects. The target words were either frequent (eight occurrences) or  
36 infrequent (two occurrences). Half of the target words were also highlighted  
37 with gestures, forming a deictic link to the referential content (i.e., the *icons*  
38 on the accompanying weather charts [six in total]). All other words in the  
39 weather report ("padding" words) were also controlled for frequency such that  
40 no padding word was more frequent than the frequent target words. Overall,  
41 the text consisted of 292 word types (mean number of syllables/clause = 7.85).

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1 Gullberg et al. Adult Learning After Minimal Exposure to Natural Language

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3 The highlighting gestures were scripted, and to ensure a reliable deictic link  
4 among gesture, speech, and weather charts, the temporal and spatial accuracy  
5 of the gestures was controlled by frame-by-frame analysis of digital video  
6 allowing for 40 ms accuracy.

7 The weather report was presented audiovisually by a female native  
8 speaker of Mandarin Chinese who read the text in Chinese characters from a  
9 teleprompter while gesturing as directed. In all of the experiments, we presented  
10 the weather report to participants prior to the experimental session proper. To  
11 ensure that participants did not watch it strategically for a particular task, they  
12 were all given the general instruction to “watch the film.” Throughout, we  
13 tested native speakers of Dutch with no knowledge of Mandarin Chinese, as  
14 ascertained through an extensive language background questionnaire (Gullberg  
15 & Indefrey, 2003).

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## 18 **The First 7–14 Minutes of Contact With an Unknown Language**

### 19 **Word Recognition After 7 and 14 Minutes**

20 Segmenting input in a new language is a crucial first step in language acquisition.  
21 This is a challenging task, especially in situations of untutored language  
22 learning. Words do not come with predefined breaks between them, but learners  
23 must rely on cues in the input to detect word forms. Furthermore, for adult  
24 L2 learners, it is likely that cues acquired in the first language (L1) influence  
25 analysis of the incoming string in the second language (transfer or crosslinguistic  
26 influence). The segmentation problem can obviously be facilitated in  
27 tutored situations in which teachers or native speakers may adjust their articulation  
28 to emphasize word boundaries through so-called teacher or foreigner talk  
29 (e.g., Ferguson, 1975). Mostly, however, learners must identify word strings  
30 on their own. The difficulties this causes are manifest in learner-typical behavior  
31 such as the production of chunks or formulas (for an overview, see Wray,  
32 2009) where word boundaries are not necessarily observed at early stages (e.g.,  
33 words in early French learner language such as *levolur* “steal/thief” and *lepeje*  
34 “money/pay” (Perdue, 2006, p. 860) with unanalyzed “prefixes” reminiscent of  
35 articles). However, previous studies have shown that adult L2 learners draw on  
36 fine-grained acoustic cues to detect word boundaries and segment auditory L2  
37 input using both language-specific phonetic and phonotactic information from  
38 the L1 (Broersma, 2005; Cutler, 2001; Cutler, Mehler, Norris, & Segui, 1986;  
39 Cutler & Otake, 1994; Flege & Wang, 1990; Weber & Cutler, 2006) and more  
40 general acoustic information such as aspiration (Altenberg, 2005; Barcroft &  
41 Sommers, 2005) to do so. Studies in the field of artificial language learning

2  
3 also suggest that L2 learners are able to use statistical transition probabilities  
4 between syllables to determine likely word boundaries (e.g., Saffran, Newport,  
5 & Aslin, 1996; Weiss, Gerfen, & Mitchel, 2009; and articles in this ~~issue~~ volume).  
6 Studies of the types cited provide important evidence on learners' strategies  
7 and use of cues. However, they leave open the question of what learners are  
8 capable of at the very outset of learning, especially at first contact with a new  
9 natural language presented as continuous speech.

10 We probed native Dutch speakers on word recognition in Mandarin Chinese  
11 after 7 and 14 mins of contact (Gullberg et al., in press). The learners, who had  
12 no knowledge of Mandarin Chinese, watched the Chinese weather report, and in  
13 a subsequent surprise word recognition task, they had to decide whether sounds  
14 played had been heard earlier. In contrast to studies targeting fine-grained  
15 acoustic cues, we examined the effect of gestural highlighting (presence ~~s~~ vs. *e*  
16 absence) on participants' performance on the assumption that the presence  
17 of a gesture might increase the saliency of a string contributing to improved  
18 segmentation. We also investigated the effect of word frequency (eight vs. two  
19 occurrences) and word length defined as number of syllables (one vs. two).  
20 Number of syllables was chosen because it has previously been shown that  
21 monosyllabic items may cause difficulty of perception in certain contexts (e.g.,  
22 Dommergues & Segui, 1989).<sup>1</sup> Finally, we examined the effect of amount of  
23 exposure, comparing performance after 7 and 14 min of input.

24 The results showed that after 7 min of Chinese input, participants more  
25 accurately recognized frequent than infrequent words and were also more ac-  
26 curate on disyllabic than on monosyllabic words. Participants in fact showed  
27 a no-bias toward monosyllabic words, consistently rejecting them. Moreover,  
28 word-internal backward transition probabilities (TPs; the probability of  $x|y =$   
29  $\text{freq } xy / \text{freq } y$ ) affected accuracy but only for frequent disyllabic words occur-  
30 ring eight times; that is, the higher the word-internal TP and the more frequent  
31 the word in the weather report, the better participants recognized it. In contrast,  
32 word-external TPs had no effect on the accuracy scores, providing a possible  
33 explanation for why monosyllabic words were poorly recognized and rejected;  
34 that is, because monosyllabic words by definition only have word-external TPs,  
35 they are harder to recognize. Interestingly, there was no difference between  
36 participants who had had 7 versus 14 mins ~~of~~ exposure. Finally, the presence  
37 of gestural highlighting had no effect on word recognition at these levels of  
38 exposure.

39 These findings overall suggest that adult native Dutch speakers with no prior  
40 exposure to Mandarin Chinese can segment the Mandarin sound stream, leading  
41 them to correctly recognize a disyllabic word that has occurred as little as eight

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3 times in the continuous auditory speech input when it is subsequently presented  
4 in isolation. The frequency effect is interesting in that it stresses the difference  
5 between very small increments. Four occurrences in sustained speech were not  
6 enough for word recognition to take place (low frequent in the double-exposure  
7 group), but eight occurrences were (frequent in the single-exposure group);  
8 there was a numerical improvement between 6 and 16 occurrences, although it  
9 was not statistically robust. A study testing word recognition in native Dutch  
10 speakers and English speakers with no knowledge of Dutch similarly found  
11 that both native and nonnative listeners recognized words repeated 10 times  
12 in isolation, but nonnative listeners did not recognize words repeated four  
13 times in continuous speech in sentence context (Snijders, Kooijman, Cutler, &  
14 Hagoort, 2007). Additions in small increments can thus make a big difference  
15 to nonnative segmentation skills.

### 16 17 **Sound to Meaning Mapping After 7 and 14 Minutes**

18 The mapping problem—that is, the linking of meaning to identified word  
19 forms—is a vital part of acquisition and one that has received comparatively  
20 more attention than the segmentation problem. In the child language literature,  
21 word learning, lexical, and vocabulary acquisition is often discussed in terms of  
22 “fast mapping” (Carey & Bartlett, 1978) whereby children supposedly “learn”  
23 a new word after a single or very few encounters in the input, typically during  
24 the so-called vocabulary explosion around 18–24 months (e.g., Clark, 2003; for  
25 a discussion of what “learning” might mean, see Bloom, 2004). In L2 studies,  
26 it is generally recognized that adults are competent vocabulary learners, but  
27 they are rarely granted the capacity for fast mapping.

28 A large body of literature investigates adult L2 learners’ acquisition of  
29 productive and receptive vocabulary, the role of consciousness and attention  
30 for lexical acquisition, and implicit and incidental word learning (e.g., Bogaards  
31 & Laufer, 2004; DeKeyser, 2003, for overviews; Ellis, 1994; Hulstijn, 2001,  
32 2003). Many studies focus on word learning through reading, showing that  
33 adults can learn new words without instruction while reading for comprehension  
34 after two to three encounters (e.g., Horst, Cobb, & Meara, 1998; Hulstijn,  
35 Hollander, & Greidanus, 1996; Rott, 1999). There are frequency effects such  
36 that the number of repetitions often improve learning (Kirsner, 1994), but so do  
37 cognate status and the size of the preexisting vocabulary (see Hulstijn, 2003, for  
38 an overview). As in the case of the segmentation problem, very little is known  
39 about adults’ capacity for vocabulary acquisition at the outset when no existing  
40 L2 vocabulary constrains learning of novel items and when words are presented  
41 in continuous speech without any didactic intent. Whether or not adults can fast



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3 map under such circumstances is not known (see Rohde & Tiefenthal, 2000,  
4 for a study on fast mapping with training).

5 In another set of experiments (Gullberg et al., in press), we examined  
6 whether adult native speakers of Dutch can extract meaning from Mandarin  
7 Chinese input and map it onto sound strings from the input—that is, whether  
8 they can map a sound string to a target icon from the weather report. A new set  
9 of native speakers of Dutch with no knowledge of Mandarin Chinese watched  
10 the weather report and then participated in a surprise auditory picture-word  
11 matching task, for which they had to decide whether sounds matched a weather  
12 icon shown on the screen. The experiment focused on the target nouns from  
13 the weather report (e.g., sun, cloud). Again, we examined the effect of word  
14 frequency, gestural highlighting, word length, TPs, and amount of exposure on  
15 participants' performance. The results indicated that participants were signifi-  
16 cantly more accurate on disyllabic items that had been frequent and gesturally  
17 highlighted in the weather report. As was the case for word recognition, word-  
18 internal backward TPs had an effect on accuracy such that the higher the  
19 word-internal TP and thus the more frequent the word, the more accurately the  
20 word was paired with the appropriate weather icon.

21 Again, the findings suggest that adult native Dutch speakers with no prior  
22 exposure to Mandarin Chinese can map meaning to disyllabic strings in the  
23 Mandarin sound stream that have occurred as little as eight times in the in-  
24 put in combination with a gesture to form a link to the referential content on  
25 the weather charts. The effect of gestural highlighting is not surprising and  
26 tallies well with studies showing that viewers integrate the information con-  
27 veyed by gestures to improve comprehension (e.g., Beattie & Shovelton, 1999;  
28 Butterworth & Itakura, 2000; Langton, O'Malley, & Bruce, 1996). Studies in  
29 other domains also suggest that contextual, visual cues such as the speaker's face  
30 and mouth improve lexical learning (Davis & Kim, 2001; Reisberg, McLean,  
31 & Goldfield, 1987). More newsworthy is the observation that the mapping  
32 of meaning to word form at these earliest stages seems to require accumu-  
33 lative cues to take full effect such that gestures and frequency must work  
34 together.


### 35 36 **Extracting Regularities and Generalizing: Phonotactic Information** 37 **After 7–14 Minutes**

38 In addition to lexical learning, acquisition crucially involves the capacity to  
39 generalize away from the input and encountered exemplars to the formation of  
40 categories and the establishment of regularities or “rules.” Traditional L2 stud-  
41 ies have given a lot of attention to the (longitudinal) development of regularities

2  
3 in production, especially in the domain of morphosyntax, arguing for devel-  
4 opmental sequences and stages typical of all interlanguage and at least partly  
5 independent of source and target language structures (e.g., Klein & Perdue,  
6 1997; Meisel, Clahsen, & Pienemann, 1981 *inter multa alia*). In the domain of  
7 comprehension, studies of artificial language learning in turn typically show that  
8 adults are capable of using statistical and prosodic information such as pauses  
9 for morphosyntactic rule formation even of non-adjacent and nested types after  
10 exposure to constrained artificial languages (e.g., de Diego-Balaguer & Lopez-  
11 Barroso, this issue; Folia et al., this issue). Again, despite all of these efforts,  
12 it remains unclear whether adults can detect abstract regularities in the input  
13 and generalize such regularities to novel items after minimal exposure to ~~the~~  
14 natural language (for morphological learning after longer exposure to natural  
15 language, see Davidson, this issue).

16 We were interested in whether adults can extract phonotactic information,  
17 that is, highly abstract information about the sound structures, from continuous  
18 natural language input in a new language. It has been suggested that phono-  
19 tactic acquisition shows frequency and statistical effects such that novel words  
20 with low transition probabilities between segments are judged as non-words  
21 compared to words with relatively higher segmental TPs which are instead  
22 judged as pseudo words, that is, as possible words in the language (Frisch,  
23 Large, Zawaydeh, & Pisoni, 2001).

24 We tested whether Dutch adults could detect syllable structure violations  
25 in Mandarin Chinese after minimal exposure, and whether they could apply  
26 phonotactic knowledge derived from the input to new items of the language  
27 (Roberts, Dimroth, & Gullberg, 2010). As earlier, participants watched the  
28 weather report and then completed a surprise lexical decision task in which  
29 they listened to sounds and had to determine whether they were “real Chinese.”  
30 We tested two groups with 7 versus 14 min of exposure to the weather report.  
31 We also tested a third control group with no input at all in order to control for the  
32 fact that even Dutch speakers with no formal knowledge of Mandarin Chinese  
33 have a preconceived idea about what Mandarin sounds like. The experimental  
34 materials consisted of real monosyllabic words, half of which had appeared  
35 in the weather report (e.g., *yun2* “cloud”) and half of which were new, and  
36 monosyllabic words containing phonotactic violations. A set of filler items had  
37 violations consisting of three- and two-consonant clusters word-finally (e.g.,  
38 *alst, ans*) or word-initially (e.g., *spra, sna*). These Germanic-sounding cluster  
39 violations were assumed to be easy to reject for Dutch speakers as not being  
40 Mandarin. The experimental test items consisted of CVC syllables ending in  
41 an illegal word-final consonant in Mandarin (e.g., *gam*).

2  
3 The results showed that all three groups correctly rejected all of the filler  
4 three-consonant cluster syllables and word-final two-consonant cluster syllables  
5 as not being Mandarin Chinese even without exposure to the weather report. For  
6 word-initial two-consonant clusters, everyone was at chance. Most strikingly,  
7 judgments about the experimental CVC violation syllables were at chance for  
8 the control group, but with increasing exposure participants <sup>e</sup> more accurately  
9 rejected the illegal CVC syllables. In other words, even without exposure, Dutch  
10 speakers know something about both Mandarin Chinese and Dutch phonotactic  
11 structure, but, crucially, they are also able to draw on minimal and complex  
12 natural language input to extract information about the sound structure of  
13 the new language. Importantly, the ability to identify illegal CVC syllables in  
14 Chinese must stem from an analysis of the new language input and cannot be  
15 based on transfer of L1 distinctions, ~~as~~ CVC syllables of this type (e.g., *gam*)  
16 are acceptable in the source language Dutch. These results provide evidence  
17 not only for an ability to roughly segment and recognize items previously  
18 encountered but also for an  ability to generalize phonotactic knowledge to new  
19 items after as little as 7 min <sup>v</sup> contact.


because

### 21 Neural Correlates of Word Recognition

22 To complement the behavioral studies, we have also examined the neural cor-  
23 relates of the first minutes of learning of a new language. To date, most neu-  
24 roimaging studies investigating the neural correlates of learning new words  
25 have presented participants with isolated novel word forms (Breitenstein et al.,  
26 2005; Cornelissen et al., 2004; Davis, Di Betta, Macdonald, & Gaskell, 2009;  
27 Grönholm, Rinne, Vorobyev, & Laine, 2005; Mei et al., 2008; Raboyeau et al.,  
28 2004; Wong, Perrachione, & Parrish, 2007), often paired with pictures of novel  
29 or familiar objects providing the meaning of the novel words. Although there is  
30 only partial overlap between the brain regions reported to be activated in these  
31 studies, some regions, such as the left inferior frontal cortex, the premotor  
32 cortex, the bilateral inferior parietal cortex—in particular, the supramarginal  
33 gyri—the insula, the left posterior temporal cortex, and the hippocampus, have  
34 been consistently found to be involved in word learning.

35 Naturalistic L2 exposure shares with these studies the aspect of the percep-  
36 tion and storage of novel word forms (if successfully segmented) but differs with  
37 respect to the additional demands due to the segmentation of possible words  
38 out of the continuous speech. We were therefore interested to see which of the  
39 previously observed regions would also be activated during the processing of  
40 naturalistic continuous speech in an unknown language and hence be related  
41 to successful word form segmentation. Unlike the sequential presentation of

2  
3 novel words used in previous studies, however, blood flow changes measured  
4 during the exposure to weather report video clips are not well suited for stan-  
5 dard functional magnetic resonance (fMRI) analyses, because they are based  
6 on a statistical model that takes into account the temporal order and duration  
7 of conditions. In a recent study (Veroude, Norris, Shumskaya, Gullberg, &  
8 Indefrey, 2010) we therefore used a model-free approach, assessing the so-  
9 called functional connectivity—that is, correlations between the fluctuations  
10 of hemodynamic activation of spatially distinct areas (Friston, Frith, Liddle,  
11 & Frackowiak, 1993). During rest, functionally related brain regions display  
12 correlations in the fMRI time courses (Biswal, Yetkin, Haughton, & Hyde,  
13 1995), and temporary changes in correlations between brain regions can be the  
14 result of task performance. Waites, Stanislavsky, Abbott, and Jackson (2005),  
15 for example, found an increase in the correlations between regions involved in  
16 a language task in the resting state after performance of the task.

17 In our study we assessed the functional connectivity of the regions previ-  
18 ously reported to be involved in word learning during resting periods of 5 min   
19 before, between, and after two presentations of the Mandarin Chinese weather  
20 report. In addition to motor-related regions (supplementary motor area [SMA]  
21 and insula) that typically show strong interhemispheric connectivity, we found  
22 the left and right supramarginal gyri to show increasing functional connec-  
23 tivity over time, reaching highest connectivity during the second run of the  
24 weather report movie and the last resting-state period. Furthermore, during the  
25 last resting-state period, the connectivity between the supramarginal gyri was  
26 stronger for a subgroup of participants that showed some ability to recognize  
27 Chinese words (“learners”) compared to a subgroup that performed at chance  
28 level on a postexperiment word recognition test (“non-learners”).

29 Taken together, these findings suggest an involvement of the supramarginal  
30 gyri in the successful segmentation and storage of phonological representa-  
31 tions of Chinese words. This interpretation is supported by an fMRI study  
32 by McNealy, Mazziotta, and Dapretto (2006), who used an artificial language  
33 paradigm to study the neural correlates of the ability of listeners to segment  
34 “words” out of streams of CV syllables based on statistical cues, such as dif-  
35 ferent frequencies of syllable co-occurrence. These authors found that hemo-  
36 dynamic activation in bilateral posterior temporal and inferior parietal regions,  
37 including the supramarginal gyri, increased more strongly as a function of ex-  
38 posure duration when the language stream provided cues to word segmentation  
39 than when it did not.

40 Whereas the supramarginal gyri only showed connectivity differences be-  
41 tween learners and nonlearners after exposure to the weather report, we found

2  
3 two other region pairs (left insula and Rolandic operculum as well as left SMA  
4 and precentral gyrus) to show stronger connectivity for learners only before  
5 exposure to the weather report. These regions are known to be involved in  
6 articulation and phonological rehearsal. One somewhat speculative interpre-  
7 tation might thus be that learners and nonlearners differed with respect to a  
8 predisposition to involve the speech motor system during perception.  
9

### 10 Discussion and Conclusions

11 The findings from the experiments reviewed here suggest that adult learners are  
12 able to deal very efficiently and quickly with very complex input even in the  
13 absence of instructions. They are able to extract segmental, word-form-related  
14 information, and lexical meaning from the context and map it onto word forms  
15 identified, and finally, to extract abstract, phonotactic information and generalize  
16 it to novel items not encountered in the input after as little as 7 min of contact  
17 with an unknown language. This is a remarkable feat. The results complement  
18 findings from statistical language learning studies indicating that TPs between  
19 syllables help learners identify words. However, given the statistical properties  
20 of the naturalistic input in this study, with much higher word type counts and  
21 lower TPs than is typical in artificial language learning studies, it is perhaps not  
22 surprising to find that TPs within words are the only relevant ones and, moreover,  
23 that learners draw on both TPs and item frequencies at the levels of exposure  
24 we are investigating here. That is to say, there is a powerful statistical reckoning  
25 mechanism at work that takes into account both the micro-regularities provided  
26 by TPs and the coarser statistics provided by whole-word forms. This seems  
27 to be an efficient solution for dealing with the messier input that is typical of  
28 natural languages.  
29

30 Further, to solve the task of identifying contextual meaning and mapping  
31 it onto word strings, learners combine gestural deictic links between icons and  
32 word forms with TPs and item frequency to home in on relevant form-meaning  
33 pairs. Again, learners exploit all available information in remarkably efficient  
34 fashion, but it is noteworthy that cues need to accumulate to take effect at these  
35 levels of exposure. That is to say, gestures on their own are not sufficient for  
36 meaning mapping, as is often assumed in the literature considering the attention  
37 directing properties of gesture for L1 acquisition (e.g., O'Neill, Bard, Linnell,  
38 & Fluck, 2005).

39 Importantly, the findings from this study complement existing stud-  
40 ies of implicit learning, showing that adults can extract both form- and  
41

2  
3 meaning-related information from sustained speech even in the absence of  
4 conscious learning efforts. It is important to be able to show that learners can  
5 do this at the outset of learning even when they do not have vocabularies  
6 and grammar to guide further learning. It is also important to show that the  
7 same mechanisms posited in artificial language learning studies work when the  
8 input consists of complex natural language. It has been suggested in the tradi-  
9 tional acquisition literature that the quest for meaning drives acquisition (e.g.,  
10 VanPatten, 2002), an assumption supported by the robust finding that content  
11 words are acquired before function words by both child and adult learners, by  
12 tutored and untutored learners alike (e.g., Clark, 2003; Klein, 1986; Kotsinas,  
13 1983). However, whereas the quest for content may be a primary *conscious*  
14 driving force, segmentation must precede it (see Carroll, 2001, for the same  
15 argument) and that must happen in the absence of identified meaning. The word  
16 recognition data from this study suggest that such learning is possible.

17 The neurocognitive study, drawing on model-free fMRI analysis, which al-  
18 lows for the study of neural structures involved in the processing of naturalistic  
19 audiovisual L2 input, provides important evidence that there are both preexist-  
20 ing and learning-induced neural differences in the supramarginal gyri between  
21 learners who are more or less successful at word recognition observable after  
22 no more than 14 min of exposure. An important implication for neurocognitive  
23 studies of language learning is that the supramarginal gyri thus appear to be  
24 implicated in creating phonological representations of possible L2 words after  
25 a short exposure to a new language. The findings also have two theoretical  
26 implications for L2 studies. First, the L2 literature on age effects or matura-  
27 tional constraints on L2 acquisition has often offered neurological arguments  
28 to account for adults' less successful L2 acquisition, mainly in production, ap-  
29 pealing to loss of *plasticity* in the adult brain (for overviews of such arguments,  
30 see e.g., Birdsong, 2006; DeKeyser & Larson-Hall, 2005; Singleton & Ryan,  
31 2004). This view of the adult learner as neurologically inflexible clearly has to  
32 be modified in view of findings from comprehension studies indicating rapid  
33 neurological adjustment to new input after as little as 14 min (see also other  
34 articles in this *issue*).

35 Second, the observation that there are preexisting neural differences be-  
36 tween more or less successful learners is relevant to the literature on individual  
37 differences and the thorny issue of language learning aptitude (e.g., Dörnyei,  
38 2005). More specifically, the findings suggest that one cause of individual dif-  
39 ferences in the word segmentation ability might be related to the recruitment  
40 of the speech motor system during perception.  
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volume

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3 The experiments presented here are the starting point for a range of fur-  
4 ther investigations. The question of possible maturational constraints on L2  
5 acquisition—both in production and in comprehension—remains a key issue  
6 for language acquisition studies. Whereas the literature has often focused on  
7 end states, recent studies comparing child L2 learners of different ages suggest  
8 that younger children progress via a different route toward the target language  
9 than older children (e.g., Dimroth, 2008). Furthermore, age interacts with the  
10 linguistic domain under study. For instance, adults are faster, or at least not  
11 slower, than children in initial stages of acquisition for morphosyntax (e.g.,  
12 Slavoff & Johnson, 1995) or phonology (e.g., Loewenthal & Bull, 1984). In the  
13 lexical domain, in contrast, children are sometimes thought to be both faster  
14 and better than adults (Carey & Bartlett, 1978). However, Markson and Bloom  
15 (1997) found that adults were significantly better than 3- and 4-year-olds at  
16 single-word retention when tested immediately after training but that their ad-  
17 vantage disappeared when tested a week after exposure. This suggests that rate  
18 and degree of retention need to be treated separately. Again, most studies of this  
19 type have not examined the very initial stages. We have begun to probe these  
20 issues by comparing word recognition and phonotactic learning in 6-year-olds  
21 and adults (Roberts et al., 2010).

22 A further issue to examine concerns how adults' initially efficient process-  
23 ing of new language input tallies with their observed slower progress once  
24 the system becomes more complex. To study changes in the rate and degree  
25 of retention requires carefully crafted longitudinal studies, which remains an  
26 important challenge for the future. A related issue is to study the relationship  
27 between the earliest skills in reception and production in order to elucidate how  
28 the two modes of language use may interact in acquisition.

29 In conclusion, the studies presented here suggest that at the earliest stages  
30 of L2 acquisition and in the absence of preexisting knowledge to bootstrap  
31 and boost learning, the adult learning mechanism can deal efficiently with very  
32 little input and with very complex input. The adult learning mechanism appears  
33 to be considerably more powerful than typically assumed in the L2 acquisition  
34 literature. The combination of statistical properties, frequency, contextual cues,  
35 and a limited search domain such as the weather report all provide a powerful  
36 scaffolding system allowing the adult learning mechanism to extract consid-  
37 erable amounts of linguistic information implicitly. Although above-chance  
38 performance on experimental tasks is a far cry from successful L2 acquisition,  
39 we believe that we have made some progress toward answering Clive Perdue's  
40 call for more empirical research on the earliest stages of acquisition, which is  
41 crucial to our understanding of L2 acquisition.

3 **Note**

4 1 Artificial language learning studies suggest that TPs between syllables are an  
 5 important factor in learning (e.g., Aslin, Saffran, & Newport, 1998; Perruchet &  
 6 Desaulty, 2008). However, in natural language material like the weather report,  
 7 which displays a high number of word types, TPs are quite different from the  
 8 minimal systems used in artificial language studies. To be able to compare possible  
 9 effects of item frequency and TPs, we computed TPs for the weather report and, as  
 10 expected, we found that word-internal TPs were higher than word-external TPs,  
 11 meaning that words of two syllables may be better recognized than monosyllabic  
 12 items.

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### Queries

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