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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

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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.,

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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

Q2 see references

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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**

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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).

Q3 ✓

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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

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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).¹ 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

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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*).


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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 ^e/ 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*) because
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 ^v contact.

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

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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

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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
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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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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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