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Psycholinguistic techniques and resources in second language acquisition research

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Abstract

In this article, a survey of current psycholinguistic techniques relevant to second language acquisition (SLA) research is presented. I summarize many of the available methods and discuss their use with particular reference to two critical questions in current SLA research: (1) What does a learner's current knowledge of the second language (L2) look like?; (2) How do learners process the L2 in real time? The aim is to show how psycholinguistic techniques that capture real-time (online) processing can elucidate such questions; to suggest methods best suited to particular research topics, and types of participants; and to offer practical information on the setting up of a psycholinguistics laboratory.

Keywords

psycholinguistics, parsing, syntactic processing, reading, on-line methods, eye-tracking, self-paced reading

I Introduction

Since the publication in *Second Language Research* of Marinis' article 'Psycholinguistic techniques in second language acquisition research' in 2003 (Marinis, 2003) the number of published studies in second language acquisition (SLA) that employ online methods has expanded dramatically. SLA researchers are beginning to use psycholinguistic techniques often together with more traditional methods in an attempt to address central questions in the field of SLA, as they become more aware that acquiring the target language involves both the accumulation of second language (L2) knowledge and the ability to put that knowledge to use during real-time processing (White, 2003). As regards

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learners' (grammatical) knowledge, one debate that can be addressed using online methods is that concerning whether L2 learners' persistent problems with morphosyntax in the target language even at extremely high levels of proficiency is best characterized as a representational deficit (e.g. Hawkins and Chan, 1997; Tsimpli and Dimitrakopoulou, 2007) affecting learners exposed to the L2 after puberty and in whose first language (L1) the relevant features are not instantiated, or a processing problem, relating to difficulty in accessing the relevant knowledge in real time (e.g. Goad and White, 2006; Prévost and White, 2000; for a recent review, see Slabakova, 2009). A comparable debate also amenable to online techniques is that surrounding recent proposals that highly advanced L2 learners' continuing difficulties with the target language grammar may specifically affect phenomena at the (external) interface levels between, for instance, syntax proper and discourse (e.g. Sorace, 2011; Sorace and Serratrice, 2009; Tsimpli and Sorace, 2006; for a recent overview, see the journal *Linguistic Approaches to Bilingualism* 1(1) 2011). Furthermore, for beginning and/or non-literate learners and children, some methods are useful for tapping knowledge that may go beyond what they are currently able to produce in spontaneous speech or to judge in metalinguistic tasks.

As well as being useful for assessing L2 knowledge, online techniques are critical to the more recent endeavor to address theoretical questions about the nature of learners' real-time processing in comparison to that of native speakers. This research field has burgeoned in the last decade, with debate focusing on whether differences between (adult) L2 learners' and native speakers' processing are a reflection of a fundamental difference between monolingual and L2 processing procedures (Clahsen and Felser, 2006) or of more general processing capacity limitations (e.g. Hopp, 2010; for discussion on this debate, see Roberts, 2012).

In Section II, a summary is presented of the main types of psycholinguistic techniques available, illustrated with brief descriptions of studies that have made use of them, and suggestions for future research. Here, recent SLA research that demonstrates how online techniques can speak to current issues in SLA and L2 processing research are described in more detail. Following this, Section III provides some practical information on hardware and software for researchers wishing to run psycholinguistic experiments.

II Online methods for psycholinguistic research

Research on monolingual sentence processing has shown that on encountering each word in the input, readers or hearers immediately attempt interpretation: grammatical knowledge is applied (the input is *parsed*) and also semantic, pragmatic, discourse and world knowledge is accessed and integrated to assess and ensure that the resulting interpretation is plausible and appropriate (for discussion on parsing models, see Van Gompel and Pickering, 2007). Online methods can tap into these processes as they occur and thus both comprehenders' knowledge and their ability to use this knowledge in real time processing can be deduced.¹ Many techniques rely on a speed response to determine the processes underlying language comprehension; that is, comparatively slower reading/listening or reaction times (RTs) to a stimulus item – in comparison to a control condition – indicates a processing cost of some sort. This comparative cost is often measured via the time it takes to make a strategic response like a button-push, and can be observed, for instance, when readers or listeners have trouble integrating a current word into the

ongoing analysis of a sentence due to ungrammaticality, complexity or ambiguity, or when an interpretation has led to misanalysis, and revision or re-interpretation takes place. In probe recognition tasks, where participants make timed lexical or semantic decisions to target items, faster responses indicate that one (part of a) constituent is more active in working memory than another. Below I describe some of the methods that can be used for psycholinguistic experiments with L2 learners.

I Self-paced reading/listening

During self-paced reading (SPR) or listening (SPL), the input is presented word by word or phrase by phrase. Each participant reads or listens to the input at his or her own speed, pushing a button to bring up the next word or segment once they have processed the current chunk of the sentence/utterance, and repeating the procedure until they have processed the input to the end. The time it takes for each button-push is recorded by the experimental software and thus the technique provides a measure of incremental processing, a measure of how (comparatively) easy or difficult it is to integrate each unit into the comprehender's current analysis of the input. The majority of SPR studies employ the non-cumulative (moving window) technique, where each button-push removes the current word from the screen and replaces it with the next (Just et al., 1982). As in monolingual research, SPR is useful for the study of the comprehension of ambiguous input and how recovery from misanalysis is achieved (e.g. Dussias and Piñar, 2010; Juffs and Harrington, 1996). For example, Roberts and Felser (2011) looked at the word-by-word reading time profiles of advanced Greek learners of English as they read 'garden-path' (GP) sentences like those in (1).

- (1) The journalist wrote the book (the girl) had amazed all the judges.

The learners' attempt to integrate each new word into their current analyses led them to initially analyse the ambiguous NPs (*the book/the girl*) as direct object of the initial verb (*wrote*), since they were faster to press the button to bring up the next word in the condition where the NP was a plausible direct object of the initial verb (*read the book*) in comparison to where it was an implausible direct object (*wrote the girl*). Such evidence of incremental processing is reported in other L2 studies using both SPR (e.g. Dussias and Cramer Scaltz, 2008; Jackson and Bobb, 2009; Juffs, 2006; Juffs and Harrington, 1996) and eye-tracking during reading (e.g. Frenck-Mestre and Pynte, 1997).

As well as being useful for investigating incremental parsing, SPR has been used to assess learners' sensitivity to certain ungrammaticalities during L2 processing (e.g. Hopp, 2010; Sagarra and Herschensohn, 2011), and thus is useful in assessing the state of a learner's current interlanguage (Selinker, 1972). Some studies report that although learners can judge violations correctly as ungrammatical during offline metalinguistic tasks, they may not be able use the information online if the phenomenon under investigation is not instantiated in their L1 (e.g. for subject-verb agreement violations with Chinese L2 learners of English, see Jiang, 2004; and for Spanish and Chinese L2 learners, see Lee, 2002; and for tense-aspect agreement violations with French and German L2 learners of English, see Roberts and Liszka, 2008). These L1 influence findings support the view that if a grammatical feature has not been acquired by a learner via the acquisition of their L1, it may not be acquired to native-like levels (see Hawkins and

Chan, 1997), or at least, it may not be possible to make use of such information in real-time processing (for eye-tracking data, see Keating, 2009). Hopp (2010) argues against this position in a series of experiments using traditional grammaticality and speeded grammaticality judgment tasks (GJTs), as well as SPR for comprehension. He investigated L2 learners' knowledge and real-time use of L2 morphosyntax with advanced and near-native Russian, Dutch and English learners of German. As well as recording learners' grammaticality judgments on ungrammatical sentences involving number (2) and case agreement (3), the learners' word-by-word reading times were examined to see if they slowed down on these ungrammatical sentences and those with dispreferred Object–Subject word order (4).

- (2) * Er glaubt, dass der Förster im vorigen Jahr den Angler
 He believes that the forester (SG) in previous year the fisherman (SG)
 umgebracht **haben**.
 killed have
- (3) * Er glaubt, dass **die** seit langem vermisste **Hund**
 He believes that the (FEM) since long missed dog (MASC)
 im Garten gefunden wurde.
 in the garden found was
- (4) Er denkt, dass **den** Hotelier im August **der** Gastwirt
 He thinks that the (ACC) hotelier in August the (NOM) landlord
 angezeigt hat.
 sued has

Of particular interest are the near-native groups' results: in the offline judgment task, all performed like the Germans, even the English group, in whose L1 gender is not instantiated, which the author argues is evidence against the idea that such phenomena cannot be acquired if not available via L1 acquisition. Online, the L2 learners were slower to process dispreferred word-order sentences and ungrammatical items, suggesting that they could employ their grammatical knowledge during real-time processing. Also of interest was the finding that when the German natives were under processing pressure (the items were presented in speeded-up conditions), their online judgment performance was reduced such that it mirrored that of the Dutch and English L2 learners. For example, their ability to correctly judge sentences with gender errors dropped; this is a finding that supports the idea that it may be processing difficulties that underlie learners' non-native-like performance in some circumstances (Goad and White, 2006).

2 Sentence matching

SPR (and eye-tracking during reading) can therefore be used to good effect to assess the grammatical knowledge of advanced L2 learners, but may not be best suited for learners of lower levels of proficiency, children, or those from communities unused to taking part in experiments. Since auditory stimuli is used and no metalinguistic judgments need to be made, two tasks that can be usefully applied with such populations are self-paced listening (e.g. Felser et al., 2003; Schimke, 2009) and auditory sentence matching (SM).

Verhagen (2009) used auditory SM to investigate the knowledge of verb placement in beginning Moroccan and Turkish L2 learners of Dutch. The assumptions behind SM with

auditory stimuli is the same as for SM with written input²: when people encounter two sentences and are asked to decide if they are the same, their responses are faster when the pair matches. Furthermore, making a matching decision to grammatical sentences elicits faster responses compared to matching ungrammatical sentences (a grammaticality effect), indicating that grammatical knowledge is accessed/applied. One should provide sentences that are longer than 7 words, so that participants process the input rather than memorize it as chunks. Since the critical comparisons are between grammatical and ungrammatical matching pairs, the filler items contain the same number of non-matching pairs – half of which being grammatical and half ungrammatical – so as to elicit ‘no’ responses from participants, and to disguise the experimental manipulations.

Verhagen used negation to investigate verb placement, and created four different experimental (matching) conditions: sentences with raised lexical verbs, appearing left of the negator (5a) and ungrammatical items, with non-raised lexical verbs (5b). Parallel conditions were created with auxiliary verbs (6).

- (5) a. Kees en Sander roken niet in de trein (LEX–NEG)
 ‘Kees and Sander smoke not in the train’
 b. *Kees en Sander niet roken in de trein (*NEG–LEX)
 ‘Kees and Sander not smoke in the train’
- (6) a. Kees en Sander hebben niet in de trein gerookt (AUX–NEG)
 ‘Kees and Sander have not in the train smoked’
 b. *Kees en Sander niet hebben in de trein gerookt (*NEG–AUX)
 ‘Kees and Sander not have in the train smoked’

The learners listened via headphones to the sentences, which were presented consecutively, and made a push-button grammaticality response. The learners were faster to match pairs of sentences containing non-raised lexical verbs (*NEG–LEX) vs. raised lexical verbs (LEX–NEG). This corresponded to the pattern observed in their free production confirming that, at this stage in their development, they did not yet raise lexical verbs. When presented with auxiliary sentences as in (6), however, they responded significantly faster to those grammatical in the target language, that is, when in raised position (AUX–NEG), in comparison to ungrammatical auxiliary sentences (*NEG–AUX). This was the case even though auxiliaries were yet to be observed in their production.³ Thus, if one were only to look at these learners’ free production, it would seem that they had as yet no knowledge of verb raising in Dutch, but the results of the SM task tapped into this emerging knowledge. Verhagen argues that these results support a structure-building account of SLA, and the theory that the acquisition of auxiliaries is a crucial first step in the acquisition of verb raising with lexical verbs (see Becker, 2005; Jordens and Dimroth, 2006).

3 Cross-modal priming

Another task that relies on auditory stimuli is cross-modal priming (CMP), which is particularly useful for investigating participants’ processing procedures. During CMP, participants auditorily process the input, and at some critical point during its presentation they make a response (a yes/no classification decision) as quickly as possible to a target stimulus presented on a screen and comparisons are made in response times (RTs)

between target and non-target stimuli. Faster RTs reflect greater activation levels, thus one can examine what linguistic items are more or less activated in the comprehender's mind at certain points during the uninterrupted processing of the input. For example, L1 processing studies have investigated which part(s) of an antecedent clause are reactivated at the elision site in VP-ellipsis (e.g. *The mailman bought a tie for Easter, and his brother who was playing volleyball, did ___ too according to the sales clerk*; see Shapiro et al., 2003) and in sluicing constructions (e.g. *The handyman threw a book to the programmer but I don't know which book ___*; e.g. Poirier et al., 2010), and both such experiments would yield interesting results if undertaken by L2 learners of different L1 backgrounds.

In a recent CMP study with L2 learners, Felser and Roberts (2007) investigated whether Greek L2 learners of English would reactivate a fronted indirect object (*peacock*) in object relative clauses like (7) at the structurally appropriate gap site (#1). This was observed for native English speakers and children (Roberts et al., 2007) who responded more quickly to identical target pictures⁴ (*peacock*) in comparison to unrelated targets (*carrot*) matched for frequency and syllable length.⁵ However, critically, this processing facilitation was found for identical targets only at the structurally relevant position – the indirect object gap site (#1) – and not at the control position (#2), approximately 500 ms earlier in the input (see also Love et al., 2003), where there was no difference in the participants' responses to the target pictures. Overall, this suggests that for natives, dislocated elements are reactivated during real-time processing only at grammatically-defined positions (compare Traxler and Pickering, 1996).

- (7) John saw the peacock to which the small penguin gave the #2 nice birthday present #1 in the garden.

Although the learners showed facilitation in the processing of the identical targets in comparison to the non-target words like the natives, this effect was visible at both the gap and the control positions, suggesting that the fronted argument (*peacock*) was maintained in memory throughout the processing of the sentence, rather than reactivated only at the gap position (#2). The authors argue that their results support the 'shallow structure hypothesis' (SSH; Clahsen and Felser, 2006), which proposes that post-puberty L2 learners' processing is lexically-driven and involves linear parsing heuristics rather than being a structurally-determined process as they assume for L1 processing (e.g. Pickering et al., 2000). The SSH is supported by the results of studies that show non-native-like syntactic processing irrespective of learners' L1 background (e.g. Marinis et al., 2005; Williams, 2006) or limited processing resources (Felser and Roberts, 2007; Juffs, 2005), together with data that indicate learners are less able to apply structural processing principles online, for instance in the processing of relative clause adjuncts such as *Someone shot the servant of the actress who was on the balcony* (Felser et al., 2003; Papadopoulou and Clahsen, 2003; but compare Dekydtspotter et al., 2008; Dussias, 2003; for an overview, see Papadopoulou, 2006). In other words, L2 learners can establish local dependencies when they have encountered a lexical verb (e.g. Jackson, 2008; Juffs, 2005; Juffs and Harrington, 1995; 1996; Williams, 2006) but when computing long-distance dependencies during real-time processing, it is assumed that they are less able to employ (abstract) grammatical information (e.g. Felser and Roberts, 2007; Marinis et al., 2005). Arguing

against the SSH are researchers who state that L1 and L2 processing is basically identical, and any observed differences are best accounted for in quantitative rather than qualitative terms (e.g. Dekydtspotter et al., 2006; Hopp, 2009), especially since cognitive factors such as working memory limitations or speed affect L2 learners to a greater extent than native speakers (e.g. Fender, 2001; Hoover and Dwivedi, 1998; Hopp, 2009; 2010; Jiang, 2004; 2007).

4 Eye-tracking

Eye-tracking techniques can be split into those focusing on how a visual scene is assessed during spoken language processing (the visual-world paradigm), and those that investigate reading processes. In the visual-world paradigm, it has been found that hearers' eye movements are tightly locked to the auditory input, such that on hearing the name of a referent, they look within 200 ms to a picture of it on a visual display. This method has been used to study, for example, the interpretation of ambiguous subject pronouns during listening comprehension (Ellert, 2011; Ellert et al., in press; Wilson, 2009) and also predictive processing, where comprehenders create expectations of up-and-coming input on the basis of, for instance, the subcategorization preferences of verb (e.g. Kamide, 2008). This would be an interesting topic for L2 research, particularly given the idea that one way in which learners may differ from natives is in their ability to commit to an analysis during online processing in the absence of enough (lexical/semantic) information (see Havik et al., 2009; Jackson and Roberts, 2010). This task is also ideal for child language acquisition studies and/or for non-literate participants.

Eye-tracking during reading is useful for detecting readers' sensitivity to ungrammaticalities, with longer fixation times at points where comprehenders find the input ungrammatical or surprising (e.g. Keating, 2009), but it is highly effective for investigating online parsing procedures. This technique goes beyond SPR because one can examine the moment-by-moment comprehension processes in a more natural way. Furthermore, a more fine-grained reading profile can be obtained, that is, the time course of readers' use of information at different processing stages can be examined and recorded, with the earliest processing stages captured by 'first fixations' (the first time the eyes fixate on the region of interest, ROI) and 'first-pass' times, involving summing up the time spent reading the ROI from the first fixation until the eyes exit to the right or to the left. Later processing stages are reflected by how often the word was returned to for re-reading (regressions), and the total time spent reading the word or phrase (akin to the measure of global processing effort elicited by a button-push in the SPR task). Researchers should be aware, though, that there are many factors that affect the fixation times, including word length (in characters and syllables), word frequency and type (function words are fixated on approximately 25% of the time). Therefore these factors should be carefully controlled for when creating the experimental materials (for overviews, see Dussias, 2010; Staub and Rayner, 2007).

Using this technique, Felser et al. (2009) and Felser and Cunnings (2011) investigated whether advanced Japanese and German learners of English would perform like English speakers in their processing of reflexive pronouns: immediately linking a reflexive anaphor with only a grammatically appropriate (binding-accessible) NP in earlier discourse (Nicol and Swinney, 1989), following Principle A of the Binding Theory (Chomsky, 1981). Participants read short texts (8), comprising a lead-in sentence that

introduced two referents (*John* and *Richard*) into the discourse. Both referents were then reintroduced, one of which being the binding-accessible referent (*Richard*), and the other being the non-local, ‘binding-inaccessible’, but discourse-prominent referent (*John/Jane*). The gender of the pronoun was manipulated so that it agreed in gender with either the accessible and inaccessible referents.

- (8) John (Jane) and Richard were very worried in the kitchen of the expensive restaurant.
- a. John noticed that Richard had cut himself with a very sharp knife.
 - b. Jane noticed that Richard had cut himself with a very sharp knife.

The region of interest – positioned as centrally on the screen as possible – comprised the reflexive pronoun (*himself/herself*) and the following few words, to check for delayed (spill-over) effects. The first fixation and first-pass reading times showed that the learners’ earliest processing of the ROI differed from the native speakers’. Specifically, when the binding inaccessible referent matched the pronoun for gender – *John ... himself*, (8a) – the learners spent longer reading the pronoun, in comparison to when there was no mismatch: *Jane ... himself* (8b). This suggests that the learners considered the structurally-inaccessible referent as a potential antecedent, and this interfered with their earliest processing of the pronoun. This was the case even though their final interpretation of the reflexive anaphors was native-like (demonstrated in the offline grammaticality judgment tasks). No such differences were observed for the native speakers. Since the learners performed similarly, even though German patterns like English (and unlike Japanese) with no long-distance binding permitted, the authors argue that L2 learners’ earliest analyses are constrained by discourse-level factors rather than structurally-defined locality conditions as observed for native speakers, thus supporting the SSH. Comparable eye-tracking findings are reported by Roberts et al. (2008): German and Turkish L2 learners differed from Dutch native speakers in that their online interpretation of subject pronouns was disturbed by having a matching competitor antecedent in the discourse. The authors argue that it is the integration of information from multiple sources (grammar/discourse-pragmatics) that learners find more problematic than native speakers during real-time comprehension. Such results also favor the idea that it is phenomena that lie at the (external) interfaces that may cause more difficulty for learners (see Sorace, 2011; Tsimpli and Sorace, 2006), and that this problem may be best attributable to processing rather than competence factors.

In sum, the time-course sensitivity (in comparison to CMP/SPR) captures detailed reading patterns, illuminating the earliest stages of processing, and therefore addressing questions about both SLA and L2 processing.⁶

III Practical information: Hardware and software

Setting up a psycholinguistics lab to run experiments like those outlined in this article requires a dedicated space. Minimally, one needs a small, quiet room big enough for a desk to hold a desk-top computer/laptop setup and an office chair, and if possible, another desk and chair for an experimenter. For eye-tracking experiments, one must also be able to darken the room. The eye-tracking systems discussed below come with specialized

PCs/laptops, but for the experimental design and presentation packages in the other cases, the researcher provides his or her own PCs/laptops, to the required specifications. Researchers should elicit quotes directly from the providers, not only because the prices are guidelines at the time of writing, but also because in some cases reductions are offered for university researchers, and/or for multiple license purchases.

1 Stimulus preparation, presentation and data collection for reaction and reading time experiments

Most psycholinguistic experiments require that participants' responses be recorded while stimuli are being presented visually or auditorily (or both). The most commonly used software packages for this purpose are E-prime and Presentation for PC users,⁷ and Psyscope for Apple users. Each offers the ability to design and run online experiments, where the stimuli can be presented in auditory and visual modes, including videos, and data can be recorded in a number of ways, including via the recording of button-pushes (on the computer key-pad, with a mouse click, a foot-pedal or with a dedicated push-button box) or voice activation responses. Thus, experiments using probe recognition/cross-modal priming, sentence matching, online grammaticality judgment and self-paced reading/listening experiments can be set up and run with these packages.

2 E-prime

Many researchers use E-prime (<http://www.pstnet.com/eprime.cfm>) to design and run online experiments and to collect and analyse the data. E-prime has a graphical interface, and is therefore easy to use, even for those with little programming experience; it involves dragging and dropping objects onto timelines to create an experiment, although one can use the scripting language E-basic to prepare non-standard experiments. E-prime 2.0 Professional currently costs \$995 for the software package, and \$125 to \$795 for licenses. No special hardware is necessary to run E-prime 2.0, which is compatible with Microsoft Windows XP/Vista. As a minimum requirement one needs a PC/laptop with at least 512 MB RAM, CD-ROM, and a serial port. Although RTs can be recorded via the keyboard, it is recommended that the researcher use the add-on Serial Response Box (\$450) for more accurate time-stamping of responses. Recent developments to the E-prime package (2.0) include the ability to use digital films (MPEG, WMV, AVI) as stimuli during experiments, and to digitize recordings of vocalized input. Useful currently available extensions include scripts that can enable the use of E-prime with Tobii eye-trackers and for fMRI experiments (E-prime extensions for fMRI, *EEfMRI*, \$2,000). There is an online forum (<http://support.pstnet.com/forum>) where problems and questions can be posted, as well as a support line via telephone and email.

3 Presentation

Presentation is a stimulus delivery and experimental control software system available to download from Neurobehavioural Systems Inc. (www.neurobs.com) and designed for

psycholinguistic and neurolinguistic experiments (including eye-tracking, ERP, MEG and fMRI). Presentation does not use a graphical interface, but is easily programmable with a description language and control language, which makes it rather more flexible than others. Once the software is downloaded, there are online tutorials and examples, which researchers can work through to learn how to program the experiments they require. Presentation should be run on a 32-bit operating system (Windows XP/Vista/7), with Microsoft DirectX. Although the package is free to download, licenses must be purchased that give permission to run the software (one license per computer per experiment). Licenses can be purchased as USB keys ('dongles'), or via an activation code exchange procedure with the website; they cost \$80 to \$1,200 each, depending on the type and number required (http://www.neurobs.com/menu_licensing/prices). It is also possible to obtain web experiment licenses (currently \$1,000). On the website, recommended manufacturers are listed for purchasing necessary extra hardware, e.g. button response pads (\$325 from Cedrus: www.cedrus.com) and other applications. There is a forum for users to post their queries, and also a Wiki site for uploading information to share with other users.

4 Free software packages

Psyscope was developed for use on Apple Mac computers (http://psy.ck.sissa.it/psy_cmu_edu/index.html) and the most recent version Psyscope X can be used with OSX (see <http://psy.cns.sissa.it>). As with E-prime, experiments are created with a graphical interface, via the use of pop-up windows, scrolling bars and icons. The Psyscope manual provides detailed information and example experiments, and information on Psyscript, the language that can be used for programming one's own experiments (http://psy.cns.sissa.it/psy_cmu_edu/PsyMan.pdf).

Other free packages include one for Windows, from Kenneth Forster's laboratory at the University of Arizona, DMDX (<http://www.u.arizona.edu/~kforster/dmdx/overview.htm>) (for an online tutorial by Nan Jiang, see <http://www2.gsu.edu/~eslnxj/dmdx/usedmdx.html>), and Linger, a package that can be run on Unix, Windows or Mac (OSX, OS9), available from Edward Gibson's laboratory at MIT (<http://tedlab.mit.edu/~dr/Linger/>).

5 Eye-tracking systems

There are many different eye-tracking systems available. When choosing which one to purchase, one should note that there is usually a trade-off between how much a participant is free to move, and the granularity of the data that can be gathered. For instance, if interested in the time course of certain processing decisions at a fine-grained level, as in reading studies, then a faster, more accurate tracker should be used, but the participant must remain still throughout the experiment. If on the other hand, less detailed data is needed – for instance, investigating whether the participant looks at one picture vs. another – a slower, more 'remote' tracker will suffice, and this allows the participant more freedom of movement.⁸ Such a remote tracker often used in language acquisition studies is Tobii (www.tobii.com), a system that is not as fast as Eyelink (with a sampling rate⁹ of up to 300 Hz); however, it is good for visual world experiments and for use with children, because they can be allowed to move their heads during the experiment.

For reading experiments, SR research Inc offers Eyelink II (http://www.sr-research.com/EL_II.html) and Eyelink 1000 (www.sr-research.com/EL_1000.html). The Eyelink II system is a head-mounted system, whereas Eyelink 1000 employs the more comfortable chin-rest set-up, and also the possibility for remote use. Eyelink II comprises a padded headband, on which cameras that track the eyes are attached. The sampling rate is 500 Hz, and the degree of spatial accuracy is high: being less than 0.5° , one can be relatively sure the participant is looking at the required position on the screen. The Eyelink 1000 system allows for both head-supported (with a chin-rest) and remote/head-free tracking; it can thus be used with children. Using the system with head support makes for a much faster sampling rate (2000 Hz vs. 500 Hz) and greater spatial accuracy (0.25° – 0.5° vs. 0.5°).

All eye-tracking systems come with their custom-made data analysis and visual experiment creation tools, most often with a visual drag-and-drop interface (e.g. ClearView for Tobii; Experiment Builder and Data Viewer for Eyelink) allowing for the eye-fixation output to be visualized, for instance, as an overlay to the experiment stimulus, or to create regions of interest so that the data can be later analysed. ROIs can be created at the stimulus preparation stage, which is very useful for later analysis, given that eye-tracking produces vast amounts of data and the researcher is likely to be interested in only a small portion.

The approximate cost of the Tobii system is \$45,000, with the license fee costing an extra \$500 to \$1,050. Eyelink II (including computers, cabling, head-mounted unit, training and hardware warranty) is approximately \$45,000, and Eyelink 1000 is \$60,000. Experiment Builder and Data Viewer costs a further \$4,320, and additional licenses (dongles) are \$2,700. The cost of Eyelink includes on-site training (one day) to show researchers how to set up the eye-tracking lab, how to create experiments and how to handle the resulting data. Training can be purchased with a Tobii system for approximately \$1,500. Continuing support from the Eyelink and Tobii manufacturers is available throughout the duration of the license.

IV Conclusions

Despite the recent growth in the number of online studies in SLA research, many questions still remain. It is hoped that this overview has illustrated how successful psycholinguistic techniques can be in the study of important theoretical questions both in SLA and L2 processing research and that it will encourage future work that will be of great interest to researchers in the fields of both L2 acquisition and experimental psycholinguistics.

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Notes

1. I discuss language comprehension, in particular syntactic and/or discourse level phenomena, rather than production research. For an overview of L2 lexical processing, see Pavlenko, 2009; for L2 sentence production, see Hartsuiker and Pickering, 2008.
2. For written input L2 SM studies, see Clahsen and Hong, 1995; Duffield et al., 2002, 2007.

3. Similar findings are reported by Schimke (2009) in a SPL study of verb placement and finiteness in Turkish beginning learners of German and French.
4. Words (cross-modal lexical priming) rather than pictures can be used. Participants make a lexical decision (*is this a real word?*) to target a pseudo words (phonologically legal non-words) matched for length (e.g. Shaprio and colleagues).
5. Such factors affect processing times and so need to be carefully controlled for.
6. Psycholinguistic techniques can also probe the role of parsing in learning. As noted above, some research addresses less proficient learners' real-time processing (e.g. Keating, 2009; Schimke, 2009; Tokowicz and MacWhinney, 2005; Verhagen, 2009). But little work addresses how parsing L1 or L2 input contributes to the development of linguistic knowledge (for discussion, see Dekydtspotter et al., 2006; Fodor, 1998; regarding EEG findings, see for example McLaughlin et al., 2010).
7. E-Prime can also be used on MacBook Pro machines as long as there is more than 1GB of memory.
8. Note, however, that SensoMotoric Instruments (SMI) (<http://www.smivision.com/>) have recently launched a fast, remote system (sampling rate 500 Hz) called *SMI RED 500*.
9. That is, how many times per second the system can sample the position of the eye.

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