Evaluating “Intelligent Cumulative Exposure” as a new method of second language acquisition

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Abstract
Brainscape is a synchronous web and mobile flashcard program designed to improve the retention of declarative knowledge. We, Brainscape’s designers, have recently used our software to define a new adult second language learning methodology called “Intelligent Cumulative Exposure” (ICE), which offers learners a clear path from beginner through proficiency using vocabulary, sentence construction, and a carefully organized progression of translation-based content with grammatical annotations in L1. The combination of ICE with Brainscape’s software platform is significant in terms of both its new study medium (the mobile phone) and its improved application of spaced repetition where flashcard are repeated in intervals based on learners’ own confidence ratings. This paper discusses relevant theories of learning, memory, and language acquisition and uses them to demonstrate ICE’s adherence to the principles of cognitive science. Potential areas of future empirical research are also suggested to further validate Brainscape’s innovative approach to second-language acquisition.
I. Introduction

In this paper, the designers of “Brainscape”, a web/mobile study platform with a curricular approach to informal language learning, analyze the theory behind our pedagogy. Brainscape exploits current mobile technology to deliver targeted learning modules suited to the pragmatic and cognitive needs of adult learners. Our novel language drill technique, called Intelligent Cumulative Exposure (ICE), modernizes Krashen’s (1981) input hypothesis by introducing new language features one-at-a-time ($i + 1$, in Krashen’s terms) and by applying an intelligent algorithm that repeats concepts in a pattern determined by the learner’s own confidence ratings. Our emphasis on this drill-based approach is a departure from recent trends in Computer Assisted Language Learning (CALL) which favor media-heavy “immersion” environments with a focus on recognition rather than production (e.g., Rosetta Stone).

The need for a theory-based approach to mobile learning is evidenced by the rapid proliferation of pedagogically weak applications on the market. As of February 2010, over 11,000 education applications were downloaded on iTunes alone (148apps.biz), but most of these had little or no implementation of incremental curriculum-based learning strategies and made no use of metacognition (i.e., “thinking about thinking”), spaced repetition, or synchronization with the learner’s progress on complementary web applications. The few iTunes apps that do have a web-based complement (e.g., Byki) do not offer a convenient way for the learner to reflect her web-based advancements on her mobile phone, nor vice versa. This is a significant shortcoming given the increasing number of adults who use educational web and mobile applications sporadically during short breaks in their day (Farago, 2009).

The sections that follow will illustrate how Brainscape’s ICE method both captures the majority of the learning efficiencies of multimedia desktop applications and offers learners a convenient, accessible, and synchronous way to study from any stationary or mobile device. First, we will establish the tenets behind ICE and the software designs that make it possible. Second, we will review Krashen’s Input Hypothesis and the importance of incremental exposure. Third, we will discuss how Brainscape’s particular application of spaced repetition, called “confidence-based repetition”, optimizes the use of such incremental exposure by ceding control to the learner. Finally, we will defend Brainscape’s somewhat unconventional application of production and translation as a self-assessment mechanism. With some further validating research, the confluence of these learning strategies into a single device-independent platform could open some interesting new paths in the evolution of CALL.
II. Overview of Brainscape Software and Language Curriculum

The novelty of the ICE method stems from a combination of both a new software platform and a new way of organizing language concepts into a progressive curriculum. This section takes a closer look at Brainscape’s software and curriculum to prepare us to better assess its cognitive merits in subsequent sections.

The Brainscape Software Platform

The goal of Brainscape’s software designers was to create a simple study solution for adult learners whose study habits are sporadic and unpredictable. Since a typical learner might study for varying lengths of time and separate her study sessions by varying intervals, Brainscape lets curriculum designers carefully break concepts into their most fundamental building blocks which can be systematically repeated in customized intervals of time. This allows the learner to easily “pick up where she left off” without the fear that she will have to manually review concepts from previous sessions.

Figure 1 shows the core Study screen of the Brainscape mobile application. This particular sample study screen shows a flashcard from one of the lessons in the Spanish curriculum, although the software supports learning for various other types of content such as geography, test prep, sciences, etc. Users are easily able to select which deck (or deck mix) that they wish to study by using the Library screen (see Figure 2).

As the user progresses through Brainscape’s multimedia flashcards, she is asked to manually reveal each answer (rather than typing an answer or selecting from multiple choices), in the same way that she would “flip” a traditional flashcard. Then, once each answer is displayed (and the correct audio is played), the user is asked to rate her confidence in the concept on a scale of 1-5. Brainscape’s algorithm uses this judgment of learning (JOL) to determine the amount of time before the flashcard will be displayed again, with higher JOLs yielding a longer interval of time before the concept will be reviewed.

1 Remember that for every screen on Brainscape’s mobile application, an analogous screen exists on the web application at www.brainscape.com. Users can keep all their progress synchronized between the two platforms to allow for seamless transition of study environment.

2 The reason for using 5 confidence levels (really 6, counting unseen cards or “0s”) is that it conforms to the usual category range for self-assessments, such as on Likert scales and on similar confidence-based repetition programs in history such as SuperMemo. It also conforms to the six normalized categories that Son (2004) employed to prove learners’ preference for massing difficult items and spacing easier ones. Furthermore, we propose that providing the user with an odd number of options enables her to respond neutrally (by selecting “3”), as opposed to being forced to choose a more or less confident rating when given an even number of options.
Some educational scientists may question the value of allowing users to simply reveal the answer rather than requiring a direct input or selection of the answer. Yet Brainscape's designers deliberately eliminated that assessment step in order to engage the learner's active recall faculties (rather than simple recognition) and allow for a larger number of quick repetitions in a shorter amount of time. The benefits of an increased number of exposures are expected to be larger than the costs of eliminating user-provided response, as we will explore later (see Confidence-Based Repetition).

In either case, such a reliance on self-assessment allows Brainscape to provide a unique set of progress visualization tools for the active learner. First, the Mastery bar on the Study screen shows the user a weighted average of all her confidence ratings. [A deck of all un-seen cards (0s) would have a Mastery of 0%, and a deck of all perfect 5s would have a Mastery of 100%.] Second, the individual bar graphs on the Stats screen (see Figure 2) show the relative number of cards in each confidence category 0-5, to help the user better assess her relative comfort levels with items in a given deck or study mix. Finally, the Library screen allows the user to view the average Mastery for all decks or "packages" (collections of decks) across her entire account. This diverse metacognitive snapshot provides the user with unique guidance for what subjects she needs to study.

The convenience and scalability of the Brainscape platform allows for the creation of a diverse set of educational content to be deployed to a large number of learners. We will now profile how Brainscape has used its platform to organize its language curriculum and to develop its ICE methodology.

**The Brainscape Language Curriculum and ICE**

The aim of Brainscape's language curriculum designers was to create an effective, cumulative study experience within the Brainscape software platform. There are
Currently many competing language applications on the market that allow for some degree of flashcard study and spaced repetition, but most exist as merely a series of thematic vocabulary sets (e.g. 400 food & restaurant terms, 600 medical terms, etc.) that contain both useful and obscure terms. The Brainscape language curriculum instead aims to provide a clear path from beginner through proficiency and to improve the learner’s understanding of sentence construction in addition to just vocabulary. Decks in the Brainscape Spanish curriculum are carefully ordered by increasing complexity, based on analyses of language corpora, comparison with other language textbooks, and Brainscape’s own word usage studies.

Figure 1 (in the previous section) showed a typical “card” in the Brainscape Spanish curriculum. Notice that the underlining of a word or concept helps the user identify which element of the sentence is “new”, while simultaneously reminding her that she should already know the other words and concepts from previous flashcards. The introduction of only one new concept per card allows for constant reinforcement of previous topics and facilities the adherence to the \((i + 1)\) approach recommended by Krashen’s input hypothesis (see Incremental Exposure).

These features and others have led the Brainscape team to name its language methodology “Intelligent Cumulative Exposure” (ICE). The principal characteristics of Brainscape’s ICE method are summarized in Table 1.
<table>
<thead>
<tr>
<th>Feature / Method</th>
<th>Description</th>
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<tbody>
<tr>
<td><strong>Active Recall</strong></td>
<td>Each learning objective is presented as a cue-target pair, or “flashcard”</td>
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<tr>
<td><strong>Production</strong></td>
<td>The cue is usually in the form of a full native-language (L1) sentence that must be translated to the target language (L2)</td>
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<tr>
<td><strong>Manual Display of Target</strong></td>
<td>Each correct target sentence is revealed by the user at will after a mental/verbal attempt at production; there is no typing or selection from multiple choices</td>
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<tr>
<td><strong>Audio</strong></td>
<td>A recording of the correct native-speaker pronunciation is played upon display of target, and can be manually replayed at the user’s command</td>
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<tr>
<td><strong>Confidence-Based Repetition</strong></td>
<td>The user is instructed to rate her judgment of learning (JOL) in each flashcard, which is used to determine how long until it will be reviewed again. (Higher confidence items are displayed less frequently – just as people tend to study flashcards on their own – see Son &amp; Metcalfe, 2000.) The “Progressive Study” feature allows users to include concepts from previous lessons in their current study mix to ensure that older low-confidence items do not become stale.</td>
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<tr>
<td><strong>Color-Coded Confidence</strong></td>
<td>The flashcard’s background color matches the color of the associated confidence ratings. This reminds the user of what she rated the concept last time (thereby giving her a metacognitive anchor), while providing feedback (a changed color) when she provides a new confidence rating</td>
</tr>
<tr>
<td><strong>Annotation</strong></td>
<td>The learning objective is usually explained or clarified using L1, in a supplementary note underneath the correct target L2 sentence.</td>
</tr>
<tr>
<td><strong>Incrementalism</strong></td>
<td>Only one new learning objective is covered at a time. All other aspects of a given flashcard’s sentence (including both vocabulary and grammar) have appeared in previous cards.</td>
</tr>
<tr>
<td><strong>Chunking</strong></td>
<td>Flashcards are grouped into “decks” with a common theme or objective (e.g. The Present Tense, Adjective Gender &amp; Placement, etc.)</td>
</tr>
<tr>
<td><strong>Vocabulary Focus</strong></td>
<td>Supplementary “vocab enrichment” decks are dispersed between the “lesson” decks and are simply L1/L2 word pairs - little annotation needed</td>
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The Brainscape approach is unique as it combines aspects of traditional media such as textbooks, flashcards, and spaced audio repetition into a single incremental activity. In fact, our initial Spanish application covers the vocabulary and grammar equivalent of at least two full years’ worth of secondary school textbooks. Yet unlike textbooks, which usually teach a lesson first and then give examples, Brainscape introduces each concept through a sentence (which the user presumably translates incorrectly on first exposure) and then provides the explanation. This progression of production, correction, and explanation is similar to how a conversation with a native speaker would be if that native speaker could give constant feedback on a sentence-by-sentence basis – a technique that would be very difficult to maintain in live interaction. Few school or university classes could ever offer such personalized attention for so many hours of potential practice.

A main difference between ICE and true conversational immersion is the use of translation and grammatical explanations in L1 (i.e. the native language). While some scholars and programs such as Rosetta Stone assert that the most effective language exposure is exclusively through L2 (i.e. the target language), Brainscape maintains that L1 is often an appropriate adult learning facilitator in certain settings - a question we will explore later. In effect, the design of the Brainscape methodology is based on several assumptions and premises that we will address in this paper.

**Assumptions in the Brainscape approach**

- Whenever possible, real interactive conversation with a native speaker is a preferred method activity for improving language proficiency
- When real conversation is unavailable, there is a role for autonomous software that replicates many of the benefits of conversation (e.g. listening, production, correction, and explanation) without the need for a live instructor
- It is possible to achieve many such conversational benefits using simple modularized sentence snippets with audio accompaniment, grammar annotation, and confidence-based repetition
- Confidence-based repetition is the most effective way to optimize a learner’s use of study time for modular concepts such as vocabulary words or grammatical rules
While large ongoing conversational stories are preferred in order to provide broader context, they cannot be modularized into individual “cards” that are repeated independently at user-determined intervals; it is therefore acceptable to use stand-alone sentences instead.

Translation is an acceptable means of requiring the user to generate (or “produce”) the target L2 sentences, in the absence of a larger conversational or environmental context.

Mobile devices are an ideal medium for the application of these drill-based techniques, given their portability, convenience, and limited screen size.

Since many adult learners still do enjoy a web-based study experience, a technology that allows both web and mobile study (with synchronization of progress) is a convenient innovation.

Nevertheless, no matter how effective that ICE could ever be, a behavioral drill-based web/mobile activity can never be sufficient as a single way to learn a language, but should rather be used as a complement to other activities such as reading, listening, speaking, writing, and engaging in thoughtful analysis and interaction.

In the sections that follow, we will evaluate these assumptions, describe how the ICE methodology builds upon existing theory, and suggest the types of future research that could lead to enhancement of the ICE methodology.

III. Incremental Exposure

One of the largest and most frustrating challenges for second language learners is encountering a conversation, movie, or reading passage that has so many unfamiliar words as to render it incomprehensible. Without a significant amount of supporting context and/or scaffolding, the ability to learn and understand the new concepts is greatly reduced (Krashen, 1985). Research as far back as Miller (1956) suggests that people are only capable of processing and remembering about seven (plus or minus two) new items at a time.3

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3 Miller’s experiments centered on humans’ ability to remember a series of numbers. Considering that a foreign language words or concept may be more complex than a simple digit, it would be reasonable to assume that the digestible number of new concepts (without repetition or reinforcement) may be even less than seven at a time.
Brainscape’s curriculum designers therefore strive to make every flashcard incremental, so that there is only one new learning objective per flashcard. Although concepts are repeated in their own specified intervals after their first exposure, new concepts are always displayed in the Brainscape-defined order. No supporting word or concept may be casually used in a sentence unless it has been previously explained, and no new concepts are introduced until the user’s confidence in previously taught concepts has reached a sufficient level.

Krashen (1981) suggests that an incremental approach is the most effective way to maximize mental processing of new language concepts while minimizing cognitive load. According to his Input Hypothesis, each chunk of input should be presented at a level of difficulty equal to $i + 1$, that is, just a bit beyond the learner’s current ability ($i$), but not so difficult as to seriously impair comprehension nor so easy that no new language challenges are encountered. “By encountering a constant but small proportion of new language forms among familiar ones in a meaningful, communicative context,” Krashen explains, “the learner is able to infer the meaning and function of the new forms using the linguistic and extralinguistic context provided by the situation (p. 100).”

An educator using Brainscape as curriculum support would therefore be encouraged to combine Brainscape’s modularized, incremental exercises with carefully placed reading passages that are within the user’s region of proximal learning. Print and multimedia passages containing primarily familiar concepts will provide much more effective practice while allowing the learner to focus greater mental energy on the few new concepts that are introduced within. Without an anchored confidence-based mechanism such as Brainscape to measure learners’ readiness for certain activities, it would be much more difficult to manage such a fully-scaffolded curriculum.

**IV. Confidence-Based Repetition**

Perhaps the most important component of ICE is what Brainscape calls Confidence-Based Repetition (CBR). This technique maximizes the efficiency of study time by tailoring a specific repetition interval to each individual concept, rather than prescribing a blanket spacing pattern to a collection of concepts in a lesson. CBR derives its name from the concepts of Confidence-Based Learning, in which assessment is based largely upon the learner’s self-evaluation (Hunt 2003), and Spaced Repetition, in which study is spread over time rather than crammed all at once (Dempster 1988). Brainscape applies CBR to previously reviewed concepts while incrementally introducing new concepts as confidence in previous concepts reaches sufficient levels.
A large body of research exists suggesting that spacing study over time is the most effective way to improve retention. In fact, Janiszewski et al. (2003) shows that the usage of progressively longer inter-study intervals (ISIs) has been shown to be so effective that it is even more beneficial to long-term memory retention than other oft-emphasized factors such as verbal versus pictorial stimuli, novel versus familiar stimuli, unimodal versus bimodal stimulus presentation, structural versus semantic cue relationships, and isolated versus context-embedded stimuli. Cepeda’s (2006) review of 839 assessments of distributed practice in 317 experiments confirmed that a whopping 96% of assessments showed a statistically significant positive effect from spacing exposure over time. (See Figure 3.) Brainscape takes this theory to the next step by customizing the degree of spacing to each individual concept based on the user’s Judgment of Learning (JOL).

![The Relationship Between ISI, Retention Interval, and Memory Performance](image)

**Figure 2 - Evidence for Expanding Repetition.** Note that the optimal inter-study interval (ISI) increases in step with the retention interval. If one wishes to remember something for 30-2,900 days or longer, then there is no benefit from spacing study sessions by less than 1 minute (Cepeda et al., 2006)

While Brainscape is not the first system to apply CBR to flashcard-based software (see SuperMemo, Anki, Mnemosyne, or Smart.fm), it is the first to combine the technique with a complete language curriculum based on the cognitive techniques discussed earlier. Brainscape maintains that its application of CBR reduces both the risk of reviewing an easy concept too soon (causing a waste of study time) as well as the risk of repeating a difficult concept too late (forcing the user to learn the concept again from scratch).
Interestingly, learners seem to intuitively understand CBR on their own, even without using an intelligent software program. Son and Metcalfe (2000) show that, in the absence of time constraints, learners choose to allocate more study time to difficult concepts and less time to easy ones. (See Figure 4.) Brainscape thus automates what savvy learners already do in practice, sparing users the time-consuming task of calculating what and when to study for optimal benefit. This is particularly useful when the number of concepts to be managed becomes massive, as in the case with languages.

![The Relationship Between Judgments of Learning (JOLs), Study Time Allocation, and Memory Performance](image)

*Figure 3.* The better that participants judge themselves to know a particular item, the less likely they will want to study it again soon (i.e. to mass it), and the more likely they will get it correctly on a post-test (as indicated by the proportions over the bars). Participants were relatively accurate in their JOLs (Son, 2004).

Additionally, there are two ancillary benefits of CBR that are unrelated to the interval of repetition. First, simply requiring the learner to rate her confidence increases the strength of the memory trace in the brain. Research by Sadler (2006) suggests that the mental activity of asking oneself “Was I right?” improves retention more effectively than if the computer had simply displayed whether the learner’s answer was correct without any reflection on the part of the user.
The second side benefit of CBR is that it enables instructional designers to modularize concepts into their most fundamental digestible building blocks. This allows the user to repeat concepts more frequently than if the exercises were longer, less chunk-able activities such as reading passages or full conversations. Squire (1992) shows that each attempted memory retrieval promotes the establishment of new neuron connections in animals’ brains. Brainscape’s use of modularized CBR helps maximize the number of these recall events for humans.

Critics of confidence-based repetition lament that it does not require direct user input of an answer, and therefore does not offer the opportunity to provide right/wrong feedback to the user. There is some merit in this criticism. Corbett and Anderson (2001) and many others show that effective learning software design is indeed often characterized by frequent and varied user action and by frequent computer-generated feedback. Omitting such feedback can risk having the user “zone out” or fail to make a genuine mental retrieval attempt before revealing the answer.4

Brainscape accepts these legitimate risks but believes that the deleterious effects of “zone out” are mitigated by the motivation of the target audience — informal, adult learners. Self-directed individuals are naturally more likely to put effort into reflecting on their answers and managing their own progress, in the same way that diligent users of traditional flashcards are more likely than casual learners to create pile systems while they study. Brainscape does offer some reflective feedback by reminding users about their cumulative confidence ratings and by providing a “Mastery” statistic derived from the average confidence of all cards in a deck.

More importantly, we argue that the current alternatives to free mental recall are actually less effective from a cognitive standpoint. Simply selecting an answer from among multiple choices fails to improve future performance on more meaningful active recall activities (Pashler et al., 2007; and Karpicke & Roediger, 2006), while forcing the user to type in an answer consumes valuable time (especially on a mobile phone) and accordingly decreases the number of repetitions that can be achieved in a given span of

4 It is possible that the user’s judgment of learning (JOL) may be more accurate if she is asked to rate her JOL before the answer is displayed. Brainscape nevertheless asks for the JOL after the answer is displayed in order to control for errors. For example, if the user had rated something a 5 before seeing the answer and was then incorrect, the program would have already erroneously determined that the question should not be seen for a very long time. Asking for the JOL only after the answer creates a more positive user experience by avoiding the need to request the JOL twice. Over time, learners given appropriate feedback are able to improve their accuracy at assessing their JOLs anyway (Moreno & Saldaña 2004 and Kerly & Bull 2008).
time. Nelson and Leonesio (1988) show that when students are separated into groups graded on either speed or accuracy, the accuracy students — despite spending significantly more time on each item — make little or no gains in performance over the speed students.

Another point of concern in confidence based learning regards whether users are able to accurately assess their likelihood of remembering each concept. The Brainscape team addresses this concern in several ways. First, we remind skeptics that learners are actually quite accurate in assessing their judgments of learning (JOLs) to begin with (Son, 2004; Dunlosky & Nelson, 1994; Lovelace, 1984). Second, Brainscape’s pattern of repetition is based more on relative confidence ratings than on absolute ratings, so a preponderance of high-confidence items (e.g., 5s) will still appear in users’ study mixes as long as an equivalent amount of time is spent studying overall. Third, people are actually more likely to remember a corrected wrong answer when they previously exuded high confidence that their answer was correct and subsequently learn that it was incorrect (Butterfield & Metcalfe, 2006), especially when the exposures are spaced in time rather than massed (Barrick & Hall, 2004). This is likely because people are more surprised in such situations and therefore they reflect more on their own thinking, which helps to reinforce the correct answer. Finally, with practice, learners tend to improve the accuracy of their JOLs (Moreno & Saldaña 2004, Kerly & Bull 2008, and Berthold, Nückles, & Renkl 2007). Brainscape helps users improve such self-awareness skills and accordingly manage their own study more efficiently over time.

Nevertheless, despite these various practical and theoretical benefits, some users may not fully accept Brainscape’s ICE method without more direct computer-generated feedback. Initial user testing suggests a broad difference between the types of learners who love the idea of managing their own knowledge, and those who prefer questions requiring active user input and right/wrong confirmation. Market data should more accurately reveal the prevalence of each learning preference as Brainscape penetrates the web/mobile language learning space, while leaving open the possibility of incorporating a layer of right/wrong feedback generation in future software releases.

V. The Role of Production

Much of the existing body of linguistic research emphasizes the importance of input for effective second language acquisition (SLA), rather than the learner’s output, or production, in the form of writing or speaking (Swain, 2005). Many modern constructivist educators have therefore routinely eschewed production-oriented grammar drills in favor of video, virtual immersion environments, and comprehension activities. In many circles
the words “behaviorist” or “drill” have even taken on a negative or anachronistic connotation (Decoo, 1994).

Brainscape maintains that production-centered behaviorist drill should indeed be included as a key part of a comprehensive SLA program since the act of producing phrases or sentences in L2 “may prompt second language learners to recognize consciously some of their linguistic problems” (Swain, 2005, p. 27). Production, accompanied by corrective feedback, is a particularly useful tool when prompting learners to assess their own JOL. Furthermore, learners are naturally more likely to perform metalinguistic analysis of the grammatical rules behind a sentence when the learner herself is the one actively producing that sentence (Toth, 2006). As the learner utters and analyzes her own words, she refines her understanding of their structure, especially when corrective feedback is given (Russell & Spada, 2006).

Izumi et al. (1999) further illustrate the extent to which production practice leads to improved performance on a production-centered posttest. Participants in their experiment were instructed to generate their own written response to a given prompt, followed by exposure to a model response written by a native speaker. Results suggest that the opportunity to produce one’s own response before exposure to the model leads to significantly greater posttest scores.

Izumi’s finding is interesting given that participants were provided feedback in only one large chunk (i.e. exposure to the entire passage) rather than incremental corrective feedback for each sentence as it was written. Research by Corbett and Anderson (2001) suggests that the Izumi experiment’s performance enhancements could have been even greater if the learners had been given more frequent feedback on their correctness. The idea of regular feedback has become a standard feature of most modern educational software and video games.

Although Brainscape does not require the user to type a response, it does essentially provide sentence-by-sentence feedback by revealing the correct sentence construction (and playing the audio accompaniment) immediately after the learner has attempted to mentally generate it herself. This is as closely as an autonomous technology can approximate the experience of conversing with that ideal native speaker who provides validation after every sentence uttered. Seeing/hearing immediate multimodal feedback, along with a grammatical explanation of the new concept, helps the Brainscape user provide a more accurate confidence assessment and therefore a more optimal interval of time before that concept is reviewed.

The Role of the Mother Tongue
Critics of ICE often question its reliance on translation as the primary means of eliciting the learner’s production. Indeed, some of today’s most popular language education
companies promote their exclusive use of L2 immersion as one of their most significant pedagogical advantages. Brainscape, however, views the learner's competence in his primary language as a valuable asset in learning a new language rather than as a source of interference and confusion. We should not forget the substantial and growing body of evidence supporting the idea that use of L1 and translation is indeed useful, if not critical, to adults’ ability to assess their progress toward learning L2 (Avand, 2009; Cook, 2001; and Kern, 1994). According to Buck (1992), "the widespread rejection of translation as a language testing procedure by teachers and testers is [...] simply not warranted on psychometric grounds." There remains a large role for L1 in SLA provided that it is used correctly in conjunction with other types of engaging activities.

Brainscape highlights several benefits of using L1 and translation in its own web/mobile curriculum. First, translation may be a faster way to illustrate concepts that cannot be easily conveyed using environmental or pictorial cues. While it may be easy to elicit the L2 version of the word “apple” by showing a picture of one, it is less feasible to illustrate complex sentences like “If I’d had more money, I wouldn’t have bought such cheap shoes” exclusively in L2 without first setting up that sentence by creating time-consuming contextual background. Brainscape’s use of a single L1 cue enables it to separate L2 production exercises into quickly digestible individual sentences which can then be repeated more frequently according to the learner’s own repetition needs (see Confidence-Based Repetition). Prasada, Pinker, and Snyder (1990) show that frequency of exposure to each language aspect (phonology, orthography, vocabulary, morphology, and syntax) is the most important determinant of how fluidly the learner will be able to access it in the future.

Second, certain grammatical concepts are treated so differently between an L1 and L2 that they may benefit from a supplementary explanation in L1 in order to be fully understood within a reasonable amount of time. Anton and DiCamilla (1998) show that for complex concepts “L1 serves a critical function in students' attempts to mutually define task elements, provide each other with scaffolding help, and externalize inner speech”; and White (1991) shows that learners are best able to grasp difficult concepts like adverb placement when they are given positive or negative feedback in their native language. While adult learners are certainly capable of subconsciously figuring out grammatical structures after repeated and differentiated exposure, explanations in the familiar mother tongue can expedite the understanding process and allow the learner to progress to other topics more comfortably.

Third, mental translation is a natural and unavoidable occurrence in adult learners, since they have been conditioned for a lifetime to think in their mother tongue. Pariente-Beltran (2006) and Upton and Lee-Thompson (2001) show that even when a lesson or activity is conducted exclusively in L2, new information tends to be processed through internal
cognitive processes in L1 anyway. Incorporating actual L1 annotation into a lesson helps learners externalize those processes while helping teachers identify misunderstandings more transparently. Perhaps even more importantly, it has been shown that learners seem to prefer spending time on L1-supplemented activities anyway, since the use of L1 more effectively encourages learners to solve communication tasks on their own (Nae 2004).

Fourth, learners’ preference for L1-supplemented instruction may be accompanied by greater comfort levels while studying. Parrish (2004) and Krashen (1981) show that increasing self-confidence and reducing anxiety about language learning activities can lower affective filters and thereby improve learning performance. To the extent that using L1 in instruction makes learners more comfortable, we may be able to trade some of the benefits of staying in L2 for a net gain when the comfort of the learner is taken into account. If a learner does not study, they will not learn as much, no matter how well-grounded in theory that the system is.

Finally, the Brainscape team reminds critics that translation itself can be a valuable and applicable skill in the learner’s target language. Whether interpreting a conversation for a friend, translating a document for work, or converting one’s personal emails between L1 and L2, a language learner is likely to encounter many real-life cases in which translation skills prove useful. The importance of translation as a communication tool suggests that there exists no intrinsic incompatibility between translation and language instruction Pariente-Beltran (2006).

Brainscape aims to harness many of these benefits of corrected translation by anticipating the errors that learners are likely to make in each new grammatical learning objective, and by clearly explaining the rules (in L1) below each respective L2 sentence. While the specificity of correction may not be as intelligent as a human tutor, Brainscape expects that its annotations will address the majority of major confusions that could be associated with each concept. The benefits gained from such clarification are maximized as Brainscape maintains each concept in an optimal review cycle based on the learner’s comfort level.

VI. Conclusions and Implications

In this paper we have shown that Brainscape is an ideal software platform for the application of intelligent cumulative exposure (ICE) – an effective, flexible, and accessible means of adult second language acquisition. ICE introduces and reviews concepts in a pattern that is challenging, progressive, reflective, and highly engaging of
some of adult learners’ most useful language acquisition faculties, while incorporating the most convenient web and mobile synchronization capabilities available.

One of the most attractive aspects of this Brainscape experience is that it focuses on what computer-adaptive language learning (CALL) is good at — drill. Rather than trying to artificially create “authentic” language environments, Brainscape harnesses the fact that modern adults are nearly always connected to web/mobile technologies, and it provides them with a curriculum that can be easily accessed for short, modular study breaks throughout the day. Learners are encouraged to enrich their study using Brainscape with authentic exposure through other internet resources such as blogs, news, video clips, and language exchanges.

In fact, Brainscape’s aggregate confidence visualization features help learners to more accurately gauge how ready they are to engage in such authentic language activities, and may even help learners become better at assessing their own knowledge over time. Moreno and Saldaña (2004) and Kerly and Bull (2008) show that both children and intellectually impaired adults are able to improve their metacognitive self-assessment skills with the help of intelligent software. Considering that normally functioning adults tend to have greater metacognitive abilities than children (Metcalfe & Finn, 2008), it is reasonable to expect that the improvements in self-assessment will be even greater for adult users of Brainscape. Metacognitive reflection is among the most critical skills that any learner can develop to improve her study efficiency (Black & William, 1998).

Nevertheless, theoretical support is no substitute for specific empirical data. Brainscape is currently planning research and experimentation to further validate the efficacy of its software and approach. Questions to be explored include (1) To what extent does the use of ICE empirically improve language-learning performance? (2) Are particular language aspects (e.g. lexical, syntax, idioms, etc.) better suited to ICE than others? (3) What factors in ICE usage most influence the accuracy of learners’ self-assessment? and (4) Are concepts and skills acquired through ICE transferable to other language activities? We hope these studies shed more light on how computer systems can support language learning and how some recently criticized principles of language instruction — production, repetition, and translation — can be revived to form a stronger pedagogy.
VII. References


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