13 Automaticity and Second Languages

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1 Introduction

There are a number of different ways to understand second language acquisition (SLA), and each has its own strengths and limitations. One currently popular approach to SLA sees it as a special case of complex skill acquisition. From this point of view, one can ask whether SLA shares elements in common with other forms of complex skill acquisition such as learning to play the piano, developing mathematical abilities, or acquiring expertise in making medical diagnosis. In attempting to identify elements that might be common to all forms of complex skill acquisition, cognitive psychologists have focused on a number of issues, including the role of motivation and commitment (Ericsson, Krampe, and Tesch Roemer, 1993; Howe, 1990), the contribution of innate predispositions to mastery in the skill domain (e.g., a talent for language or music; Howe, Davidson, and Sloboda, 1998; Simonton, 1999), the role of practice (Ericsson and Charness, 1994), the operation of memory and attention (Gopher, 1992), and the question of why there exist individual differences in attainment (Ackerman, 1989; Obler, 1989; Obler and Fein, 1988; N. Segalowitz, 1997), among others. One aspect of skill acquisition that has long attracted considerable attention is the development and the role of "automaticity" in performance. This will be the focus of the present chapter.

Questions about automaticity are really part of a larger set of questions about the role played by attention and effort in skill acquisition. The interconnection between automaticity, attention, and skill can be appreciated by considering the following observation, which nearly everyone can attest to. As one's skill level in a domain increases, the amount of attention and effort required to perform generally appears to decrease. For example, when we begin learning to drive a car, we invest considerable effort in order to perform well, paying close attention to our every action and decision. We are usually aware that our performance can be easily disrupted by relatively trivial distractions, such as someone talking to us. After some amount of practice, however, our skill level improves and, along with this, we no longer experience performing as being as effortful as before. We are now able to pay attention to concurrent events that previously would have disrupted us. Indeed, we often interpret such an escape from the need to concentrate as evidence that skill level has improved. Why, then, does performance become less effortful and more resistant to interference? According to many authors, what has happened is that a number of the underlying components of the performance have become automatic, and it is this change that reduces the need for attention and effort.

As will become clear in a moment, the term *automatic* has a number of different technical meanings. Nevertheless, psychologists generally use the term in a sense similar to what is meant in ordinary language when we say, for example, that an automatic shift car changes gears without deliberate intervention by the driver, in contrast to a standard shift car which requires the driver to perform a manual operation. Thus, when we perform aspects of a task *automatically*, we perform them without experiencing the need to invest additional effort and attention (or at least with significantly less effort and attention). When the activity does become automatic in this sense, we often also find that performance has become relatively immune to disruption by potentially interfering events, such as external sights, sounds, concurrently performed tasks, intruding thoughts, or the like. Also, performance appears to be more efficient; it is faster, more accurate, and more stable. Such a transition from non-automatic to automatic performance seems to be a part of nearly all skill acquisition. In language learning, increased performance efficiency can be seen as contributing to fluency, that is, the ability to use language rapidly, smoothly, and accurately. For this reason, understanding what automatic processing is and how it comes about is important for understanding SLA and how to enhance language learning experiences.

This chapter contains five further sections. Section 2 considers how automaticity has been operationally defined by experimental psychologists. This section deals with what is perhaps the most important issue of all: what automaticity refers to. Section 3 reviews the concept of automaticity as it is found in theories of skill development, including SLA theory. Section 4 discusses some illustrative ways automaticity issues have figured into SLA research. Section 5 discusses the pedagogical implications for SLA that are raised by research on automaticity. Finally, the chapter concludes with a speculative discussion about future directions for research on automaticity in SLA.

2 Operational Definitions of Automaticity

To investigate how mechanisms become automatic during the course of skill acquisition, we need precise descriptions and operational definitions of the terms "automatic" and "non-automatic." Such definitions abound (e.g., Neely, 1977; Newell, 1990; Pashler, 1998; Posner and Snyder, 1975; Schneider and Shiffrin, 1977; Shiffrin and Schneider, 1977). Newell (1990, p. 136), for example, describes automatic processing in the context of searching for a target (say, a particular letter) in a display (of several letters). He characterizes an *automatic* process as follows: it is fast; it is unstoppable (ballistic); it is independent of the amount of information being processed; it involves exhaustive or complete search of all elements in the display; it involves no awareness of processing; and it involves "pop-out" of the target item from the display. In contrast, non-automatic processing, also called *controlled* processing, is characterized as follows: it is slow; it is capable of being inhibited; it depends on information load; it involves self-terminating search of the display; it involves awareness; and it does not involve target "pop-out." Other authors have similarly cited clusters of properties to characterize automaticity.

There are two points to be made about such characterizations. One is that they are contrastive. That is, any given characteristic of an automatic process can really only be understood in terms of a corresponding non-automatic, contrasting characteristic. For example, processing can only be considered to be fast in relation to some slower example of processing that serves as a reference point. To demonstrate that some aspect of processing is unstoppable, we need to compare it with a situation in which we observe an ability to interrupt processing. This contrastive aspect of definitions of automaticity is important, as we shall see, because in focusing on the place of automaticity in skill acquisition it is usually necessary to also focus on closely related *non*-automatic aspects.

The second point is that this way of characterizing automaticity gives rise to a set of important questions. For example, should the automatic/non-automatic distinction be viewed as strictly dichotomous (that is, a given process must always be either automatic or not) or as end points of a continuum stretching from very non-automatic to very automatic? Second, should automaticity be viewed as a unitary construct? That is, do automatic processes always have the same characteristics (e.g., are always fast, ballistic, immune to interference, etc.)? Or does automaticity refer to a number of possibly related but nevertheless logically independent phenomena? This latter view carries the implication that there exist different types of automaticity. Finally, one can ask whether becoming automatic should be viewed as a central goal of skill attainment or, instead, should be regarded as only one part of the larger picture of what skill acquisition entails.

With respect to SLA, interest in automaticity is nearly always connected to concerns about fluency. Is fluency – which we can define here as an ability in the second language to produce or comprehend utterances smoothly, rapidly, and accurately – accompanied by automaticity? Is fluency "merely" highly automatized performance? Do the conditions that promote automaticity necessarily also promote fluency? These and related questions are addressed later in this chapter.

We turn now to consider some of the different ways automaticity has been discussed and operationalized in the research literature. It is important that we do this for two reasons. One is that, as we shall see, the term "automaticity" has been used to refer to many logically distinct possibilities in the way psychological mechanisms may operate; it is an empirical question whether automaticity in any one of these senses entails automaticity in some or all of the other senses. The second reason is that one often sees reference in the literature to processes becoming or failing to become automatic without further specification of which sense of automaticity is intended. While it may be convenient to use "automaticity" as a shorthand term, the imprecision this entails can potentially create problems for the conduct and interpretation of research on the role of automaticity in skill.

2.1 *Fast processing*

The characteristic most frequently associated with automaticity is speed of processing. It is natural to think that once a mechanism has become automatic it will operate faster than it did earlier. For example, we normally expect (and find) word recognition in fluent first language readers to be faster than word recognition in most second language readers, and such differences have sometimes been attributed to the greater automaticity underlying first language reading. Speed of operation has thus become one of the hallmark characteristics of an automatic process in virtually all theories of automaticity (see, e.g., the review by DeKeyser, 2001).

There are, however, theoretical and practical difficulties in using speed as a defining characteristic of automaticity. While automatic processing may entail fast processing, it does not follow that all fast processing is necessarily automatic. This is because "fast" is nearly always understood in a relative rather than absolute sense. It is, for example, logically possible for a given individual to exhibit faster *non*-automatic processing on one occasion than on another, or for two individuals to differ in the speed of executing *non*-automatic aspects of task performance. Hence, merely observing that performance was fast does not necessarily indicate it was automatic. Of course, our intuitions may tell us that if processing has been accomplished within some very short duration – say, word recognition within less than 200 milliseconds – then the processing most likely was automatic in some useful sense of that word. However, in this case fast processing is only being taken as symptomatic of automaticity. All one can really say is that, as a consequence of the underlying brain mechanism being automatic (in some sense other than being fast, in order to avoid circularity), processing has become very fast. This contrasts with all the other operational definitions of automaticity discussed below. There, each operational criterion is considered, without circularity, part of the definition of what is meant by automaticity, and not merely a consequence of automaticity.

Some authors have tended to rely strongly on speed as an indication of automatic processing (e.g., Lambert, 1955). For example, Magiste (1986) studied the loss of mother-tongue fluency by immigrant German speakers living in Sweden. She found that the longer immigrants had resided in Sweden, the slower reaction time (RT) was in tests of word processing in German, their first language. She attributed this loss of processing speed to a loss of automaticity. While one may agree with the ultimate conclusion that first language loss involves the loss of some automaticity, by the criteria available today these conclusions cannot really be said to have been fully supported by the evidence. Additional evidence, beyond that provided by speed, is required to justify conclusions about automaticity (see, e.g., N. Segalowitz, 1991; N. Segalowitz and Segalowitz, 1993).

Recently, N. Segalowitz and Segalowitz (1993; S. J. Segalowitz, Segalowitz, and Wood, 1998) have suggested how it might be possible to use RTs to make inferences about automaticity without simply equating *fast* with *automatic*. Suppose that after some amount of practice RTs have become significantly faster than before. Has there been an increase in automaticity? Segalowitz and Segalowitz suggest that here the appropriate null hypothesis to reject is that the change simply reflects generalized speed-up, that is, due simply to the underlying processes operating faster, and nothing more. They proposed a way to use an individual's RTs and the associated coefficient of variability (the standard deviation of the individual's RTs divided by his or her mean RT) to reject this null hypothesis. With their method of data analysis it becomes possible to test whether a given set of RTs is significantly faster than what would have been expected from simple speed-up effects alone. According to Segalowitz and Segalowitz, such an outcome would indicate that there has been a *qualitative* change in performance, consistent with the idea of increased automaticity.

This brings us to the question of whether *automaticity* really refers to a qualitative or quantitative change in performance. Many authors do use the term to refer to a qualitative change, resulting perhaps from restructuring of the underlying mechanisms involved in carrying out the performance (Cheng, 1985; Neely, 1977; N. Segalowitz and Segalowitz, 1993; Schneider and Shiffrin, 1977; Shiffrin and Schneider, 1977). The contrasting view, of course, is that automaticity entails just better, more efficient processing of the same kind as occurs when performance is not automatic.

This debate about the quantitative/qualitative nature of automaticity may, in the end, turn out to be a non-issue. The brain mechanisms underlying second language performance (as in all complex skilled activity) are numerous and diverse, and their activities are no doubt executed in a complex pattern involving serial, parallel, and cascading organization (Carr and Curran, 1994). Different component mechanisms will have different lower limits for speed of operation; some can eventually be made to operate extremely quickly (e.g., some basic perceptual mechanisms) while others will always require significantly more time (perhaps certain decision mechanisms). As various component mental activities become practiced, their time of operation will speed up, and less of the total time of performance will be devoted to those particular mental operations. Mechanisms that were formerly rate-determining because they were quite slow may, after training, no longer be so because they operate so quickly that other, slower mechanisms become the rate-determining components by default. The now fast mechanisms may operate so rapidly that the remaining slower processes may not be able to interfere with their operation. The products of these now fast mental operations may no longer be available for verbal report and hence not experienced as being consciously executed, etc. In this sense, they have become automatic. In contrast, there will remain other mental activities with speed-up limits that are too high (too slow) to ever achieve the effects just described for the fast mechanisms. Because there are differences in speed-up limits among the diverse mechanisms underlying the skill in question, the overall order in which information is output and passed from one mechanism to another may change, with the consequence that the overall organization of processing may change. Thus, out of quantitative changes in speed come qualitative differences in the way information is processed. Just such a situation has been demonstrated in the connectionist literature regarding Piagetian stage-like behavior in the learning of the balance beam problem (by McLelland and Jenkins, as described in Elman et al., 1996, ch. 3). Incremental changes in connection weights ultimately resulted, in a learning simulation, in the emergence of what observers would recognize as a qualitatively higher stage of processing. It may well turn out to be a similar story for automaticity. The explanation of automatization may in the end reduce to a question of speed-up. But if *automaticity* is to be useful it should be more than a synonym for "fast processing." It should be used for situations where the change is of significant consequence, such as a restructuring of underlying processes (N. Segalowitz and Gatbonton, 1995), even if the ultimate explanation for this restructuring is selective speed-up of mechanisms.

It is worth mentioning that some qualitative changes resulting from selective speed-up of underlying mental activities might not actually enhance overall performance. For example, errors might be made due to premature processing of certain information or failure to inhibit or redirect other processing that has now occurred too quickly. Perhaps this leads to fossilization, that is, "fluent," robust habits of incorrect speech. On the other hand, many of the qualitative changes resulting from selective speed-up might indeed enhance overall processing by, for example, leaving relatively more time available for slower, centrally controlled processing to make important decisions. An example of this would be faster reading in L2 that results from very fast word recognition. Here, not only could reading be faster because the individual words are recognized faster, but the integration of the text into a coherent schema might be more efficient overall because a greater proportion of processing time can be devoted to that activity.

2.2 *Ballistic processing*

According to another definition, a process is considered automatic when its operation is shown to be ballistic or unstoppable. This corresponds to one ordinary language use of *automaticity*, as, for example, when we say that a computer automatically booted up when the power was turned on. One of the most famous demonstrations of such ballistic processing is the Stroop color word task (Stroop, 1935). It takes longer to name the colors in which words are written when the words themselves are incongruent color names (e.g., to say the color name "green" when the word RED is written in green ink) than to name the colours of patches or strings of Xs.

Neely (1977) constructed a clever experiment demonstrating that recognition of a word's meaning by skilled first language readers of English can be automatic in this ballistic sense (see box 13.1 for more details). In his study, subjects showed that within the first few hundred milliseconds of seeing a word they could not stop themselves from thinking about its usual meaning, even though a second or more later they could override that interpretation and think about the word differently. This demonstrated word recognition to be ballistic (automatic) in the early moments of each trial.

What was clever about this experiment was that it demonstrated the subjects' inability to avoid processing a word's meaning *despite* their conscious attempt to do so. In this study, non-automatic or controlled processing was pitted against automatic processing; the results demonstrated that when processing time was limited, the output of that part of the process that was fast off the mark and unstoppable – the part Neely called automatic – prevailed. In contrast, when longer processing time was available, controlled processing overtook automatic processing and its output prevailed. Other authors have also used ballisticity or the involuntary nature of a mechanism's operation as a criterion for automatic processing (Favreau and Segalowitz, 1983; Pashler, 1998; Tzelgov, Henik, and Leiser, 1990).

2.3 *Load independent processing*

Shiffrin and Schneider have conducted a set of seminal studies examining the conditions under which practice leads to automatic performance (Schneider

Box 13.1 Neely's (1977) demonstration of ballistic (automatic) word recognition

Neely (1997) presented an experiment that neatly and convincingly demonstrated the ballistic or unstoppable, involuntary nature of meaning access upon seeing a familiar word. The design used a method of opposition in which automatic and controlled processes were set to operate in opposite directions within a trial. While the reported original study was rather complex, involving numerous conditions, the basic design of the study is elegant, and it is the general logic of that design for demonstrating automaticity that is presented here.

Methodology: Neely's subjects were instructed to make a lexical decision (word/ non-word) judgment about a target stimulus appearing on the screen. Prior to the appearance of the target subjects saw a priming stimulus, either XXX, BIRD, BODY, or BUILDING. When the priming word was BIRD, on two-thirds of word trials the target was a bird name, on one sixth ("surprise" trials) it was a body part name, and on one sixth a building-related word. When the priming word was BODY, on two-thirds of word trials the target was a building-related word, on one sixth it was a bird name, and on one sixth a body part name. Finally, when the priming word was BUILDING, on two-thirds of word trials the target named a body part, on one sixth it named a bird, and on one sixth it was a building-related word. Thus, on BIRD priming trials, the expectation was that if a real word followed, that word would be semantically related to the prime. In contrast, on BODY priming trials, the expectation was that if a word followed, that word would be semantically unrelated to the prime. Word trials with XXX as prime were followed equally often with words from the *bird*, *body*, and *building* categories. Of course, on half of all trials the target following the prime was a non-word.

The time interval between the onset of the prime and the onset of the target (stimulus onset asynchrony: SOA) was varied between 250 and 2000 milliseconds.

This design provided for the following four basic test conditions on word trials: long SOA, expect a related word; long SOA, expect an unrelated word; short SOA, expect a related word; short SOA, expect an unrelated word.

Reaction times (RTs) on word trials with XXX as prime provided baseline data (neutral prime). The primes BIRD, BODY, and BUILDING could have the effect of facilitating RTs to the target word (faster responding), inhibiting RTs (slower responding), or neither in comparison to the baseline RT data.

Results: The most interesting results came from trials where a prime is followed by a word that was *un*expected. In the long SOA condition, when the target was unexpected (e.g., BIRD–door; BODY–heart; BUILDING–door) there was inhibition. When the target was expected, there was facilitation. This demonstrated the influence of non-automatic or controlled, strategic processes based on expectations triggered by the priming stimulus. Note that facilitation occurred if the target was expected and inhibition occurred if it was unexpected regardless of whether the word was actually semantically related to the prime or not.

On the short SOA trials the story was different. When the target was related there was facilitation with respect to XXX trials even when this was a "surprise" trial, that is, the target word was not expected (e.g., BODY–heart, where the target was semantically related but a building-related word was expected). When the target was unrelated (e.g., BIRD–door; BODY–robin) there was neither facilitation or inhibition. The crucial finding here is that there was facilitation for related words, *even when those related words were not expected*.

Conclusion: This study demonstrated the influence of automatic, unstoppable processes triggered by the priming stimulus. Subjects could not prevent themselves from accessing the normal meaning of the prime word even though in the long SOA condition they exhibited inhibition with this same prime due to the mismatch with their expectations. Thus, the study demonstrated how automaticity can be operationally defined as ballistic processing, and it demonstrated that access to the meaning of words in fluent readers of English was (in the present case) automatic.

and Shiffrin, 1977; Shiffrin and Schneider, 1977). In this case, automatic processing was operationally defined as load-independent processing. A process was said to be automatic if it operated without regard to how much information had to be processed. The paradigm these authors developed involved searching a small display of items (letters, digits) for a remembered target. The researchers reasoned that if the response time to locate a target was slower the larger the display, then processing was load dependent, and by definition, not automatic. If the response time was the same to large and small displays, the items in that display could be said to have been processed in parallel – that is, all items were processed at the same time; the target just "popped" out – and processing was load independent (or automatic). They found that processing started out as non-automatic or load dependent but under certain conditions could become automatic or load independent. This qualitative shift resulted only when the stimuli were mapped onto responses in what the authors called a consistent mapping relation. This means that any item, say the letter R, that appeared as a target on a given trial always appeared only as a target during the experiment; it never appeared as a non-target element on some trial. In contrast, in some experimental conditions, stimuli were sometimes mapped onto responses in a variable mapping relation, that is, a target item on one trial might appear later on another trial as a non-target. Shiffrin and Schneider found that with variable mapping, load-independent processing was not achieved, even after thousands of trials, and even though processing became faster. This result, that automatic (load-independent) processing resulted from stimulus-response experiences involving consistent mapping, has important pedagogical implications (see below). (See, however, Nakayama and Joseph, 1998, for a different analysis of "pop-out" effects, and Pashler, 1998, for a different interpretation of Shiffrin and Schneider's results.)

2.4 *Effortless processing*

Posner and Boies (1971) reported a study that demonstrated letter processing to be automatic in the sense of not requiring attention or effort. "Effort" refers here to the expenditure of a limited attentional resource (Kahneman, 1973). The logic of Posner and Boies's study was the following. They argued that performing a primary task that is effortful (non-automatic) should interfere with simultaneously performing a secondary effortful task. They indexed such interference by the extent to which performance on the secondary task was slowed down. On the other hand, they argued that if the primary task is largely automatic and therefore does not draw attention capacity or effort away from performance of the secondary task, then there should be no slowing down on the secondary task.

In their study, subjects performed a primary task involving the following sequence of events. Subjects viewed a fixation point on a screen followed after a fixed interval by a single letter. After a short fixed interval another letter appeared in the same location as the first. Subjects had to indicate by pressing one of two buttons on a reaction time panel with their right hand whether the two letters had the same name or not (e.g., "A, a" versus "A, b"). Subjects concurrently performed a secondary task in which they pressed a different reaction time panel with their left hand whenever they heard a burst of white noise in their left ear. There was only one noise burst on any given trial and it could occur at any one of eight time positions after the fixation point appeared, up to the period after a response was made. The attention or effort required by the primary task (letter matching) was operationalized as the amount of slowing down of reaction time on the secondary task.

Posner and Boies found that when the noise burst occurred any time after the onset of the fixation point but before the onset of the first letter, reaction time to the noise burst remained relatively fast, indicating that general preparation for the upcoming first letter did not consume attentional resources. However, as the time of the noise burst occurred closer and closer to the onset of the second letter, reaction time on the secondary task slowed down considerably, indicating that mental preparation for comparing the second letter with the first did involve effort (possibly, for example, to rehearse the first letter in memory; to generate an image of what the second letter might look like given the first letter, etc.). Most interesting, however, was the finding that when the noise burst occurred within a few hundred milliseconds *after* the onset of the first letter but well before the onset of the second letter – that is, during the time when recognition of the first letter took place – there was no slowing down of the secondary task reaction time. This was interpreted as indicating that simple letter recognition itself (a highly practiced skill) did not require redirecting attention or effort away from the secondary task, whereas letter matching did (a far less well-practiced skill). In this sense, letter recognition was said to be automatic.

2.5 Unconscious processing

Jacoby has addressed the role of automaticity in recognition memory by showing how one can separate the contributions of unconscious, automatic processes from those of consciously controlled processes (Jacoby, 1991; Jacoby, McElree, and Trainham, 1999). Jacoby makes the distinction as follows. Consider the case where a person recollects information or a previously learned response that was encountered earlier during a study or training period. On the one hand, memory access for that information will be increased by the degree to which the individual is able, through deliberate effort, to consciously reconstruct or retrieve the target information. On the other hand, memory access may also be increased by virtue of the operation of automatic encoding processes which at the time of learning promote perceptual fluency with the information that is to be remembered. In other words, the encoding processes during the study/training phase will have primed representations of that information. Thus, we may remember something because we can actually recall having encountered it earlier by a process of conscious recollection. Or we may recall it because it has a "ring" of familiarity about it due to earlier automatic priming, even though we may not really be sure about having encountered it before. Usually, of course, these two sources of remembering are confounded.

Jacoby (1991) devised a process dissociation procedure to tease these two factors apart as follows. Let us refer to the two components as A (automatic) and C (conscious recollection). Jacoby designed experiments with two types of conditions, one labeled "inclusion," in which the A and C factors are set to work in the same direction to facilitate memory, and the other labeled "exclusion," in which the A and C factors are set to work in opposite directions.

For example, subjects may be given two lists of words, one presented visually, one aurally. They are subsequently given a recognition test consisting of old (previously encountered) and new items (not previously encountered). In the inclusion condition, subjects are told to say that they recognize as old all items regardless of whether they had been seen or heard in the previous lists. Here, items could be remembered either because they were consciously recollected, or because they achieved some level of familiarity from exposure during the presentation of the visual and aural lists and are now processed with greater perceptual fluency than are new items. The probability that an item will be correctly recognized in this inclusion condition will be jointly determined by the probability of conscious recollection (C) plus the probability of relying on automatic processes (A) when recollection fails $(1 - C)$, that is, $A(1 - C)$. Thus the probability of a previously seen item being correctly accepted in this inclusion condition is given by $C + A(1 - C) = C + A - AC$.

In the exclusion condition, subjects are asked to recognize as old only items that were heard, and to reject previously seen items (to treat them as new). They are told that if they see an item which they recognize as one having been seen earlier, they may conclude that they did not hear it and so should reject it. Thus, any previously seen item that is incorrectly accepted must have seemed familiar because of automatic processing and was not consciously recollected (if it had been consciously recollected, it would have been rejected). Thus the probability of incorrectly accepting an item that is to be excluded is $A(1 - C) = A - AC$. One can compare performance on inclusion and exclusion conditions. That is, one can look at actual probabilities for correctly accepting previously encountered items in the inclusion condition and incorrectly accepting items in the exclusion condition. By doing simple algebra with the above equations, one can obtain separate estimates of the contribution of automatic and conscious processes in recognition memory. Jacoby and his colleagues have conducted a number of experiments to estimate the separate contribution of automatic and conscious processes in memory (see, e.g., Jacoby et al., 1999, for a review). In principle, by using this technique it should be possible to compare the degree to which encoding of L2 versus L1 information is automatic as a function of individual differences, level of L2 mastery, type of L2 learning or exposure, etc.

2.6 *Shift to instance processing*

Logan (1988) has investigated the improvements in performance that derive from practice using "alphabet arithmetic" tasks. An alphabet arithmetic task involves dealing with expressions such as "B + 3 = E," which states that E is three letters down the alphabet after B. Logan noticed that initially reaction times to make judgments about such expressions were quite slow. After some practice they soon speeded up, but the rate of speed-up was negatively accelerated and could be described by a power function of the form $RT = a + bN - c$, where RT is the time to respond, N is the number of practice trials, and a, b, and c are constants. This relation of RT to the number of practice trials has been observed frequently in the literature (Newell and Rosenbloom, 1981) and has been proposed by Logan as a hallmark of automaticity (Logan, 1988).

Logan explains this effect as follows. Initially, the subject computes the alphabet arithmetic result by rule; the response is based on the use of an algorithm by which the expression is evaluated. The result ("B + 3 = E") is placed in memory every time it is computed. After many trials, memory becomes populated with many tokens of this information. On each trial there is a race to find the solution, a race between computing the solution by algorithm versus finding a token or instance of the solution stored in memory. Eventually, when many tokens are represented in memory, the instance-based solution is encountered sooner than the algorithm-based solution. This shift from algorithm to instance is automatization, according to Logan.

Interestingly, DeKeyser (2001) makes a convincing argument that this approach to automaticity may not be appropriate for many issues in SLA. In Logan's model, an encountered stimulus must be identical to the one encoded in memory for the instance retrieval to take place. But as DeKeyser points out, this is often not true in language comprehension. We are likely to encounter stimuli that are only similar, not identical, to those encountered before. Palmeri (1997), on the other hand, provides an exemplar-based theory in which retrieval is based on the similarity of items. This may provide a step toward making an exemplar-based approach more useful for SLA theory (but see DeKeyser, 2001, for general comments on the limitations of such approaches).

2.7 *Brain activity measures*

Finally, it is interesting to note that recent developments in brain imaging have made it possible to obtain brain-based, as opposed to behavior-based, information related to automaticity issues. The literature in this field is growing very rapidly and it is beyond the scope of this chapter to review it here (see, e.g., Fischler, 1998). One interesting finding, however, merits consideration. It is that, as an individual becomes more skilled and thus presumably more automatic in at least some of the senses described above, the size of the region of the brain devoted to carrying out the task appears, on current evidence, to become smaller (Fischler, 1998; Haier et al., 1992). This is interesting because one might have supposed that, with increased skill and increased performing experience, additional regions of the brain would be recruited to provide a richer basis for executing the task at hand. Instead, what may be happening is that processing becomes more efficient – less noisy in the sense that less brain tissue is recruited for carrying out the same task. Raichle et al. (1994) conducted a positron emission tomography (PET) study in which they compared the performance of practiced and unpracticed subjects in a task requiring participants to generate verbs in response to pictured objects. Practiced subjects responded faster, which the authors took as an indication of learning and increased automaticity. The areas of the brain that were the most active during unpracticed performance included the anterior cingulate, the left prefrontal and left posterior temporal cortices, and the right cerebellar hemisphere. These areas became markedly *less* active after 15 minutes of practiced performance. In contrast, there was increased bilateral activity in the sylvian insular cortices. The authors concluded that these areas represented two neural circuits that become differentially involved depending on whether or not a task is well learned and performed with some degree of automaticity. It should be noted that their study did not provide an independent behavioral measure of automaticity; they simply assumed that the skilled group was more automatic by virtue of being faster. Their conclusion is probably correct, although the case would have been stronger with evidence that something other than simple speed-up was involved (see earlier discussion). In general, however, it is clear that brain-based measures open an exciting range of possibilities of studying the role of automatic processes in skill development.

3 Automaticity in Skill Development and SLA

Automaticity figures as an important issue in nearly all theories of cognitive skill acquisition, including treatments of first language performance (e.g., Levelt, 1993; Perfetti, 1985) and in many discussions of second language acquisition (e.g., DeKeyser, 2001; Ellis and Laporte, 1997; Hulstijn, 2001; Johnson, 1996; Koda, 1996; MacWhinney, 1997; McLaughlin and Heredia, 1996; Pienemann, 1998; Robinson, 1997; Schmidt, 2001; Skehan, 1998; Tomlin and Villa, 1994). In general, the question of how to define automaticity (as fast, ballistic, effortless, and/or unconscious, etc., processing) is not the focus of these theories. It is usually assumed, often implicitly, that automatic processing will have one or some of the above characteristics. Rather, such theories focus on what it is that is automatized, under what conditions the process of becoming automatized occurs, and what role automatizing plays in the larger picture of skill acquisition.

3.1 Anderson's ACT theory

Perhaps the best-known general theory of skill acquisition is Anderson's adaptive control of thought (ACT) (Anderson, 1983; Anderson and Lebriere, 1998).

This theory has undergone an evolution since 1983 to the present, the most recent version appearing in a volume entitled *The Atomic Components of Thought* (Anderson and Lebriere, 1998). The theory can be implemented on computer and thus allows one to test predictions derived from it. ACT theory assumes that skill acquisition involves a transition from a stage characterized by declarative knowledge to one characterized by procedural knowledge. Declarative knowledge (knowledge "that") refers to consciously held, skill-relevant knowledge that is describable. An example might be the explicit knowledge one may have about how to form a particular grammatical construction in one's L2. Procedural knowledge (knowledge "how") is knowledge evident in a person's behavior but which the person is not consciously aware of and hence cannot describe in words. An example might be the knowledge most native speakers have about forming correct grammatical constructions in their L1. Initially, the execution of a cognitive skill involves retrieving and using declarative knowledge to solve the problem at hand, a process involving the application of production rules upon the declarative knowledge. These rules function like "procedural atoms" or units of skill acquisition (Anderson and Lebriere, 1998, p. 26). The transition from declarative knowledge to procedural knowledge through the application of production rules occurs via a process called proceduralization. This involves passing from a cognitive stage where rules are explicit, through an associative phase where rules are applied repeatedly in a consistent manner, to an autonomous stage where the rules are no longer explicit and are executed automatically, implicitly in a fast, coordinated fashion. The process is sometimes referred to as compilation, analogous to the compiling of computer routines written in a higher-level language into a lower-level language. Automaticity, then, describes an end point in the acquisition of skill in this model.

Other well-known general purpose theories of cognitive skill development include Newell's SOAR theory (Lehman, Laird, and Rosenbloom, 1998; Newell, 1990) and Meyer and Kieras's EPIC model (Meyer and Kieras, 1997, 1999). ACT, SOAR, and EPIC differ in terms of the scope of issues they address and of course, in the cognitive architecture they propose (see Meyer and Kieras, 1999, for a brief comparison of the models). For purposes of the present discussion, they are similar insofar as they accord an important place to the acquisition of automatic processing in the overall scheme of skill development.

As regards SLA, it appears that no author has yet attempted to model SLA broadly within any of the frameworks of ACT, SOAR, EPIC , or other universal theories of cognition. Nevertheless, a number of SLA theorists have made reference to such theories, especially ACT, in the course of developing their own approach to second language development. Two in particular deserve mention.

Johnson (1996, pp. 91–101) makes the point that proceduralization should result in encodings that are inflexible and non-generative because the knowledge contained in the encoding is in the production rule itself, not in the larger knowledge base. This knowledge is therefore not available for other encodings. He suggests that this might be one way to account for fossilization in learners. He goes on to point out how it is important for successful SLA that the declarative knowledge which has become proceduralized nevertheless continue to be available so that learning does not become inflexible. Johnson discusses ways to extend Anderson's model by providing for forms of declarative knowledge that come after the emergence of procedural knowledge.

DeKeyser (2001) also discusses Anderson's model in considerable detail. He draws attention to a directional asymmetry that characterizes skill acquisition, as discussed by Anderson (Anderson and Fincham, 1994; Anderson, Fincham, and Douglass, 1997). This refers to the idea that procedural knowledge, once formed, cannot generalize to other uses even if those other uses are based on the same declarative knowledge. In other words, procedural knowledge is committed to a specific operation. In contrast, declarative knowledge used in one situation may facilitate its use in another; it is generalizable. This asymmetry increases with learning. DeKeyser (1997) reports evidence for such directional asymmetry in a study of grammar acquisition with a miniature linguistic system (see below for more on this).

In Anderson's (1983) theory, the shift to using rules (the proceduralization of declarative knowledge) is a primary characteristic of automatic performance. This can be seen to contrast with Logan's (1988) instance-theory approach to automaticity, described earlier, where automaticity reflects a shift from the use of rules in guiding performance to the retrieval of specifically stored solutions (instances). This raises the question about which approach better addresses what happens when a skill is automatized, a question that is far from being resolved at the present time. Some intermediate positions are emerging in the literature (e.g., Anderson et al., 1997; Palmeri, 1997; Rickard, 1997) and are leading to revisions of earlier theories. Of special interest here is work on the learning of dynamically complex tasks, such as computerized fighter-pilot simulation games (Gopher, 1992), where one can observe the evolution of controlled and automatic processing components. For example, Shebilske, Goettl, and Regian (1999), in reviewing this area, stress how this research points to different conclusions from earlier studies that used tasks that were very much simpler. These studies of complex task learning indicate that automatic processing plays a role both early and late in training. They also indicate that executive control processes increase in importance as skill develops and that there is an interactive relationship between controlled and automatic processes.

Second language performance is itself undoubtedly complex in ways similar to task performance in the simulation games described in Gopher (1992) and Shebilske et al. (1999). For example, second language learners have to attend to many unpredictable, changing features of a dynamically complex communicative environment. The input to the L2 user can be a critical factor in shaping the way the individual engages in the "negotiation of meaning" (Long, 1996). Second language communication requires one to draw on linguistic knowledge and various cognitive strategies in order to meet immediate communicative needs, just as in the case of complex simulation games.

In recent years the study of attention has added to our understanding of the role of automaticity in the performance of cognitive skills. One interesting development is the following. Allport and Wylie (1999) report studies involving tasks where subjects have to switch task goals from one trial to the next. This generally slows performance compared to situations where no switching is involved (the full story about the effects of task switching is quite complicated and is currently the subject of much research; Allport and Wylie, 1999; Rogers and Monsell, 1995). Allport and Wylie report what they refer to as "a new form of *priming*, at the level of competing condition-action rules in procedural working memory" (p. 277). They go on to suggest that, as regards the automatic/controlled processing distinction, "task-set, the prototypical constituent of 'control', is itself subject to 'automatic' priming effects" (p. 277). This can be seen as one example of how automatic and controlled processes may interact. For an example of attention switching related to SLA see N. Segalowitz, O'Brien, and Poulsen (1998).

Another example of the interplay of automatic and controlled processes is seen in the work of Wegner (1994) on mental control. Wegner has studied why people say or do the very thing they had been trying so hard to avoid (let slip out a confidence, for example), or why it is hard sometimes to stop thinking a certain thought. He calls such "slips" the result of "ironic" processes, which he explains as follows. When we try to direct ourselves away from a target thought or utterance, we employ controlled, effortful processes to do so. However, at the same time, we must activate an automatic monitoring process in order to detect the onset of any internally generated or external stimulus that might trigger the behavior we are trying to avoid. Normally, when our monitor detects such a stimulus, the controlled process is sent into action to suppress the unwanted thought. However, if our attentional capacity is depleted for any reason (stress, information overload, etc.) then the control process will fail, leaving our automatic monitoring system free to determine our behavior. Thus, when we are tired or under stress we are more likely to make the very errors we normally try so hard to avoid. Wegner's explanation of ironic processes may be relevant to understanding the role automatic processes can play in so-called backsliding or "U-shaped" behavior (Lightbown, 1985; McLaughlin and Heredia, 1996), as when a student reverts to using incorrect forms of language that recently had been under control. The hypothesis here is that the control processes normally responsible for the student selecting correct forms are not functioning; the student may be tired, the communicative situation may be too demanding, etc. It may even be possible that new learning can lead to restructuring of existing linguistic knowledge so that some controlled process is no longer operative. When this happens, background automatic processes that normally coordinate with controlled processes by detecting error-potential situations now determine behavior alone, and the student makes the very error that she or he had so recently appeared to have learned to overcome. There does not appear to be any research addressing this hypothesis, but it seems to be one worth investigating.

4 Automaticity in SLA

It is only in recent years that SLA researchers have begun to realize the importance of understanding automaticity. Work in this area has restricted itself mainly to certain areas of performance – visual word recognition, acquisition of grammatical rules, and acquisition of orthographic knowledge. It is to be expected, however, that as techniques for measuring automaticity improve, researchers will cast a wider net. Illustrative examples from the SLA literature involving automaticity in word recogntion and grammar acquisition follow below.

4.1 Word recognition in reading

One of the basic skills that underlies fluency is single word recognition. Several authors have investigated this in the case of visual word recognition in second language reading. For a general review and discussion of issues, see Haynes and Carr (1990) and Koda (1994). The role of automaticity in visual word recognition was directly investigated in Favreau and Segalowitz (1983). They extended Neely's (1977; see box 13.1) paradigm by comparing performance in first and second language conditions, and by comparing bilinguals who were either very fluent readers of L2 (they read L1 and L2 at the same speed) or quite fluent but nonetheless slower readers in L2. As an index of automaticity, Favreau and Segalowitz used Neely's measure of ballistic processing, namely the facilitation effect in the short SOA condition for words related to the prime but nevertheless unexpected (see box 13.1 for explanation). They found that the highly fluent bilinguals showed significant facilitation in both L1 and L2, indicating automaticity in both languages, while the less fluent bilinguals showed it in L1 only. This result supported the conclusion that automaticity of single word recognition underlies fluency (see also the discussions in N. Segalowitz, Poulsen, and Komoda, 1991; N. Segalowitz, 2000). Similar studies of auditory word recognition and word production have yet to be undertaken in the same vein.

In the research just cited, automaticity was understood to imply that some kind of restructuring of processing has taken place. DeKeyser (2001, pp. 144–5) makes a useful distinction between fine-grained changes in performance and more holistic changes. For example, he points out that McLeod and McLaughlin (1986) did not find evidence for restructuring, whereas N. Segalowitz and Segalowitz (1993) and S. J. Segalowitz et al. (1998) did. DeKeyser argues that one needs to recognize the important difference between restructuring of mechanisms within word recognition (fine-grained structuring) and higher-level restructuring involved in utterance comprehension; restructuring may occur at one level but not the other.

This line of research has interesting implications for vocabulary development in L2 (as well as, of course, in L1). Many theorists argue that new vocabulary is generally acquired through learning in context (Nagy, Anderson, and Herman, 1987; Sternberg, 1987). Nation (1993) points out that a very high threshold of vocabulary comprehension is required if one is to be able to learn new vocabulary from reading a text. That is, one must have a basic vocabulary that enables one to understand on the order of 90 percent of the words of a given text if new words are to be learned effectively. Moreover, Nation (1993; also Meara, 1993) points out that the learner must have *fluency of access* to this basic vocabulary to be useful. This idea has never been directly tested, and it would seem that the techniques for studying automaticity described here could be used to investigate it. The idea that there is a threshold of automaticity in accessing basic vocabulary that must be crossed before additional vocabulary learning can take place is reminiscent of the idea (Alderson, 1984) that transfer of reading strategies from L1 to L2 cannot proceed until there is some threshold level of mastery of L2. Such transfer may also involve a threshold level of automatic processing in L2, in addition to some threshold level of knowledge of L2. Again, current techniques for assessing automaticity could be used in such a study.

4.2 Grammar

A number of authors in recent years have investigated the role of automatic processes in the acquisition of grammatical knowledge or grammar-like structure (Leow, 1998; Schmidt, 1994; Tomlin and Villa, 1994; Whittlesea and Dorken, 1993; see also contributions in Stadler and Frensch, 1998).

DeKeyser (1997) conducted a study in which learners were exposed to a miniature language system consisting of a number of artificial nouns and verbs; morphemic inflections to indicate gender, number, and grammatical case; and picture stimuli to illustrate the meanings of sentences expressed in this language. Subjects were trained and tested over a period of 8 weeks, during which they learned to comprehend (match a sentence to the appropriate picture) and produce (generate a sentence or fill in morpheme slots to describe a picture). DeKeyser was interested principally in whether the evidence of increased skill in this language-learning situation would resemble learning of other cognitive skills. His conclusions were that this generally was the case. Subjects' reaction times decreased gradually in a manner that was well fitted by a power curve of the type others have found in skill-learning situations (Logan, 1988, 1990). DeKeyser interpreted the observed decreasing speed of performance as a sign of increasing automaticity. In further discussing this research elsewhere, however, DeKeyser (2001, pp. 141–2) pointed out results from this study could be seen as evidence against Logan's instance-retrieval interpretation of automaticity. At the end of the study, the subjects had to use rules that were learned during either comprehension or production sessions in new comprehension or production tasks. One group used the rules in the same type of task (comprehension or production). A second group reversed the tasks (having now to apply a production rule to a comprehension task, etc.). DeKeyser found large reaction time and error differences between the two groups, favoring the same-task application of the rules. He argued that instance theory cannot explain this asymmetry of rule application, since once the solution instances are registered in memory they should be available equally for either type of task. He suggests that instance theory probably applies exclusively in situations where only memory is required for performance. Where production rule learning is the important requirement, as in SLA, the theory may not apply.

Robinson (1997) reported a study in which he compared the effects of focusing the attention of Japanese learners of English on grammatical form while they learned a rule governing a structure in English. The study was designed to test predictions derived from Logan's (1988) instance theory of automatization. In Robinson's study, the learners were placed in conditions that varied the kind of instruction they received (instructed, enhanced, incidental, and implicit) and the number of practice examples given before knowledge of the rule was tested. He found facilitation effects (faster responding) for old grammatical sentences in the transfer test (consistent with Logan's theory), but no effect of faster responding to examples that had been seen more frequently (not consistent with Logan's theory). In reviewing his findings, Robinson concluded that "two knowledge bases are contributing to transfer task performance" (p. 241), one that fits the description of controlled processes ("slow, effortful hypothesis testing"), the other automatic processes ("fast, efficient memorization of instances and fragments").

To summarize, the research on automaticity in grammar acquisition does not provide a tidy picture whereby learning grammatical structure proceeds simply from knowledge of examples to automatized (proceduralized) rules (ACT theory). Nor does it seem that grammar acquisition proceeds simply from the effortful application of rules to the retrieval of memorized instances. Some kind of integration of rule-based and exemplar-based processes may ultimately be called for, as DeKeyser (2001) has suggested.

5 Pedagogical Implications of Automaticity

The concept of automaticity obviously has implications for second language pedagogy (DeKeyser, 2001; Hulstijn, 2001; Johnson, 1996; Robinson, 2001; Skehan, 1998). In this section we consider two practical issues: (i) should teachers promote automaticity in SLA, and if so, why; and (ii) how should this be done?

There are several possible reasons to expect learning to benefit from automaticity. The most commonly cited one is that because automatic processing consumes fewer attentional resources than does controlled processing, the more automatic performance becomes the more attentional resources there are left over for other purposes. Thus, for example, if one can handle the phonology and syntax of a second language automatically, then more attention can be paid to processing semantic, pragmatic, and sociolinguistic levels of communication.

A second reason to favor automaticity is that once a mechanism becomes automatic it will process information very quickly and accurately, being immune to interference from other sources of information. This in itself improves the quality of performance. It has even been suggested that this consideration may be more important than the freeing up of resources (Stanovich, 1991), although there does not appear to be any research to directly test this.

Third, there are strong reasons for associating automaticity with important (but, of course, not all) aspects of fluency (N. Segalowitz, 2000; Skehan, 1998). To the extent that fluency represents the ability to speak or read quickly, accurately, and without undue hesitation, then automatic execution of certain aspects of L2 performance such as pronunciation, grammatical processing, and word recognition would, by definition, promote fluency. Fluency is, of course, a worthwhile goal in itself, insofar as it facilitates communication. In addition, however, increasing learners' fluency may increase their motivation to use the language, which in turn assists them in seeking out and profiting from increased L2 contact.

A number of authors have emphasized the importance of automaticity as one pedagogical goal in SLA. For example, Hulstijn (2001) discusses what he sees as a regrettable lack of appreciation in curriculum development for automatic skills in listening and reading word recognition, and he makes some practical suggestions regarding how this situation might be corrected. Robinson (2001) proposes ways in which learning tasks might be sequenced according to various criteria of complexity in order to facilitate automatization, among other things. Johnson (1996) develops in some detail a proposal to promote automaticity through management of the "required attention" for the task at hand.

All automaticity proposals for enhancing SLA are based, in one way or another, on the idea that extended practice, under particular conditions and circumstances, will increase fluency by developing automaticity. Where theorists differ is in terms of how explicit they are about the boundary conditions under which this will happen. We might start with a very basic question: what is the evidence that practice will enhance fluency? The literature, actually, is not so very clear on this question. A useful discussion of the issues can be found in Ellis and Laporte (1997), who review both field and laboratory studies dealing with various types of practice and their impact on SLA.

Ericsson et al. (1993) and Ericsson and Charness (1994) discuss the role of practice in other fields of expertise. They conclude that massive practice, on the order of 10,000 hours, is required to achieve expert levels in many areas of skill. In the case of L1 development, a simple calculation will show that by age 4 or 5, or even earlier, a child will have logged in hours of communicative activity on this order of magnitude. Unfortunately, this amount of time is rarely available to more mature second language learners unless they are fully immersed in a second language milieu. It is generally assumed, nevertheless, that even over shorter periods, say weeks or months, properly organized practice can lead to great improvements in second language skill. This is especially true in vocabulary learning and in the learning of chunks of language – phrases, collocations, formulaic utterances – that some have suggested is critical to the learning of syntactic patterns (Ellis, 1997). As Ellis suggests, the more automatic the learner's access to frequent language sequences stored in long-term memory, "the more fluent is the resultant language use, concomitantly freeing attentional resources for analysis of the meaning of the message, either for comprehension or for production planning . . . [I]t is this long-term knowledge base of word sequences which serves as the database for the acquisition of language grammar" (p. 139).

How, then, to best promote automaticity? Here, the challenge is the potential conflict that may exist between methods used specifically to promote automaticity and the larger methodological framework used to promote second language learning in the classroom. DeKeyser (2001) identified this problem explicitly: "It is the task of applied linguists, then, to determine how consistent practice, distributed practice, and quality feedback can be incorporated into the curriculum and reconciled with other desiderata for classroom activities, such as communicativeness and variety, not to mention how activities designed to automatize grammar can be integrated with the automatization of vocabulary" (pp. 145–6). Now, promoting automaticity is generally believed to require massive repetition experiences and consistent practice, most likely in the sense defined by Shiffrin and Schneider (1977). Traditionally, however, opportunities for massive repetition have been created in the language class through drills and practice exercises. These activities tend to operate in a way that may undermine the goals of communicative orientations to language teaching. Drill and practice are usually boring, reduce motivation, and tend to involve highly artificial, non-communicative uses of language. It has been suggested (Gatbonton and Segalowitz, 1988) that the very success of communicative language methods derives from the fact that they capitalize on an important principle of learning and memory, namely the principle of transfer-appropriate processing (Roediger and Guynn, 1996) or procedural reinstatement (Healy and Bourne, 1998). The challenge then is to incorporate activities that promote automaticity into the language learning situation in a manner that respects transfer-appropriate processing and other positive features of communicative practices (for concrete examples see Gatbonton, 1994; Gatbonton and Segalowitz, 1988; N. Segalowitz and Gatbonton, 1995). It was mentioned earlier that Shebilske et al. (1999) and others have shown that in complex skill-learning situations the transfer of automatized skills depends on the psychological similarity of the learning and transfer contexts. This consideration will be important too in designing L2 curricula. Future research will have to determine which dimensions of psychological similarity (e.g., whether the learners' intentions, feelings, etc., are important, or whether only linguistic contexts are important) are relevant to the establishment of automaticity that is transferable to new situations.

6 Summary and Conclusion

By way of summary, several points can be made. First, automaticity has been operationally defined in various ways. It is important, therefore, for researchers to be clear about which sense of automaticity they have in mind when attributing some aspect of performance to automaticity. Automaticity should not be used merely as a synonym for fast processing. Rather, automaticity refers to a significant change in the way processing is carried out (some form of restructuring). Research techniques exist for distinguishing fast automatic from fast non-automatic processes. Second, automaticity appears to be implicated in similar ways in all skill development. Third, research into the development of complex skills in dynamically changing environments points to the importance of developing automaticity in coordination with the development of attention management skills. While automaticity certainly appears to be important in the development of second language fluency, fluency also requires skilled use of controlled processes. It is important, therefore, that more research be done on the co-development of automatic processing and attention management in the acquisition of language fluency.

Where should researchers focus future work on automaticity in second language acquisition? First, in the area of measurement, it would be useful to develop practical measures of automaticity that can be easily administered in learning settings, and that do not require complex research designs involving only laboratory-based testing. In particular, it would be helpful to have measures that could be used in single case studies so that the role of automaticity in a learner's language-skill development could be traced over time. Second, more research needs to be done on how considerations of automaticity interact with the development of attention management skills. For example, it has been suggested that it is important early on for learners to have automatic access to prefabricated chunks of language stored in memory. This stored language may serve as a database from which the learner abstracts recurrent patterns, leading to the mastery of grammatical regularities. Researchers need to fill in the specific details about how this actually comes about, showing the interplay between the development of automatic access and the abstracting of regularities for the construction of rule-based knowledge or rule-like behaviors. Third, more research needs to be done on the conditions of automatization that allow skills to be transferred to new contexts, and the conditions that limit such transfer. It was suggested that the principle of transfer-appropriate processing may be crucial here; more research needs to be done on this in the context of second language development. Finally, if we are to see pedagogical benefits from research on automaticity, it is important that curriculum developers and researchers agree on how automaticity and attention are to be operationally defined, so that meaningful connections can be made between work done in the laboratory and in the field.

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