1 What Are the Key Concepts?

Identifying and understanding the factors that affect second or foreign language learning and that can predict rate of progress of acquisition and/or long-term achievement (i.e., ultimate attainment) has been one of the main areas of interest in the field of second language acquisition (SLA). Among the many individual differences that explain variation in second language (L2) learning outcomes, one that has attracted the attention of researchers since the 1950s has been language aptitude. "Language aptitude" is a catch-all, umbrella term to refer to cognitive and perceptual abilities that contribute to high achievement in language learning. In educational psychology, Cronbach and Snow (1977) used a broad definition of aptitude that included cognitive, affective, and conative (i.e., motivational) characteristics needed for achievement in a particular situation. Specifically, Snow (1991) defined aptitude as "any measurable person characteristic hypothesized to be needed as preparation for response to treatment to successful goal achievement in the treatment(s) studied" (p. 205). According to this definition, aptitude can include characteristics of the individual such as abilities, skills, previous knowledge, beliefs, attitudes, and motivation. In applied linguistics, however, the use of the term "aptitude" is more restricted. As DeKeyser and Koeth (2011) explain, the term is mostly limited to cognitive aspects of an individual that are relatively stable and largely determined by genetics and early experience. These cognitive aspects are considered good predictors of language learning and language processing holding equal all other factors such as motivation and other individual differences, which are also meaningful in the context of language learning (Doughty et al., 2010).

It is well-established that the nature of language aptitude is componential or, in other words, that aptitude is a complex of abilities. DeKeyser and Koeth (2011) suggested speaking of "cognitive aptitudes," in the plural, for learning an L2, rather than "language aptitude," and pointed out that any aptitude test would have to measure these various aptitude components. The problem is that the nature of these components is not so well-established and, as a result, researchers are still trying to put together all the pieces regarding the theoretical constructs that are relevant components of aptitude for L2 learning and processing and regarding the type of contribution they make to language learning.

The late 1950s and 1960s saw much research on language aptitude. This research, conducted under government auspices, aimed at developing measures that could predict rate of progress of language learning and that could be used for placement and selection purposes in language programs by government agencies or other organizations. Government agencies, international organizations such as the World Bank, and missionary organizations are some of the organisms that are interested in selecting employees for language aptitude in order to assign them an appropriate language to learn in terms of difficulty level (Stansfield & Winke, 2008). Fruit of this interest in aptitude in the 1950s was the creation of the Modern Language Aptitude Test battery (MLAT; Carroll & Sapon, 1959), the most well-known and most widely used measure of aptitude to date. In the 1960s, Pimsleur created the Pimsleur Language Aptitude Battery (PLAB; Pimsleur, 1966) and, in the 1970s, the US Department of Defense created the Defense Language Aptitude Battery (DLAB; Petersen & Al-Haik, 1976). The objective they all had in common was to achieve as much predictive validity as possible. Predictive validity is the ability of an instrument to predict some other variable, usually in the future. To create the MLAT, for example, the widest possible variety of cognitive tests that could be valid predictors of success in learning foreign languages was selected (Carroll, 1958). There was no theory of aptitude guiding the selection of tests (a language aptitude model was only proposed by Carroll, 1962, a posteriori, based on the empirical results of the project). In addition, "success" in learning was operationalized as course grades and these grades were mostly based on written tests and daily quizzes. Considering that the audio-lingual method was the most popular teaching methodology at the time, it is not surprising that the cognitive ability with the greatest predictive validity was rote memory. Other abilities that showed good predictive validity were also related to different types of memory (e.g., associative memory). As a result, four of the five subtests in the MLAT (Number Learning, Phonetic Script, Spelling Clues, and Paired Associates) measure different aspects of memory. Undoubtedly, written tests and quizzes involve much memory work, but it is arguable whether being good at language learning is simply a matter of memory. It is arguable as well whether obtaining good course grades means being competent in an L2, understanding by competence not only grammatical competence, but also ability for use.

From a practical perspective, the MLAT succeeded as a predictor of rate of progress in the foreign language classroom (i.e., language learning in the short run). According to the MLAT manual, predictive validity was generally high with coefficients ranging between 0.25 and 0.83, according to Pearson's r. However, the test was not created to predict L2 learning in the long run (i.e., ultimate attainment) or high-level (i.e., advanced) L2 learning. Also, from a theoretical perspective, the approach taken may be criticized for being too myopic, since the test did not effectively reflect the theoretical domain to which it was related. After the MLAT was published, Carroll (1962) proposed an aptitude model, which he developed in a bottom-up fashion from the battery of approximately twenty cognitive tests that were initially used to derive the final five MLAT subtests. The model had four components: phonetic coding ability (codifying, assimilating, and recalling phonetic material), rote memory (ability to recall words in an unfamiliar language), grammatical sensitivity (identifying grammatical functions of words or phrases in sentences), and inductive language learning ability (figuring out the rules of systematically varying language materials). Three of these components are measured by the MLAT. Inductive language learning ability was measured in the initial battery of tests, but it was not included as part of the final five-test battery. Carroll's definition of the theoretical domain of language aptitude was made before a series of rapid developments in the neighboring field of cognitive psychology. These advances in human cognitive abilities contributed to the understanding of language aptitude in applied linguistics and to a refinement of the definition of the theoretical domain. Two main areas of rapid development since the 1950s that have influenced the conceptualization of aptitude in SLA have been the areas of human memory and implicit learning.

Regarding the area of implicit learning, a key concept in this Element, research started in the late 1960s when the term "implicit learning" was introduced by Reber (1967) in a report on artificial grammar learning. The report described studies showing that learning without awareness was possible, something that is ubiquitous in the real world, the clearest example being language acquisition and socialization during infancy, but which was considered a novel finding in the context of a research laboratory at the time. Reber's research in the 1960s was carried out parallel to Chomsky's research program on a genetically determined universal grammar that was innate and that served as the basis for all language acquisition (e.g., Chomsky, 1965). Reber aimed at capturing and showing the learning process behind language acquisition in the laboratory in order to address the learnability problem that Chomsky solved with the notion of a universal grammar. In the laboratory, Reber used artificial grammar tasks, an experimental paradigm that investigates implicit learning, defined as "learning in the absence of intention to learn and in such a way that the acquired knowledge cannot be easily verbalized" (Cleeremans, Allakhverdov, & Kuvaldina, 2019, p. 1). In artificial grammar tasks, participants are asked to observe or memorize a series of symbol strings. These strings follow a complex set of rules. Then, in the testing phase, participants are asked to classify novel symbol strings as grammatical or ungrammatical, depending on whether they follow or violate the rules that controlled the structure of the symbol strings participants saw in the acquisition phase. Since the 1960s, implicit cognition has been an ever-growing field, further spurred by the research on implicit memory and its neurocognitive underpinnings in the 1980s (Schacter, 1987; Schacter & Graf, 1986; Squire, 1992). However, theory and empirical findings in this area remain controversial.

At the theoretical level, defending two simultaneous but qualitatively different, or separate, learning systems, explicit (i.e., conscious, analytical, effortful, and slower) and implicit (i.e., nonconscious, holistic, effortless, and faster), is a view consistent with dual-process or dual-system theories of higher cognition (e.g., Epstein, 1990, 2008; Evans & Over, 1996; Stanovich & West, 2000; Witteman et al., 2009). According to these theories, implicit and explicit cognition are architecturally and evolutionarily different and involve two different modes of processing, automatic and controlled. Dual theories have been challenged by researchers who view the distinction between implicit and explicit as continuous (e.g., Dienes & Perner, 1999) and who propose a single-system continuum of thought requiring different levels of consciousness from explicit to implicit. Also, in terms of language learning, it is a matter of debate whether adult learners can learn an L2 implicitly. Bley-Vroman (1990, 2009) proposed the Fundamental Difference Hypothesis, according to which there is a qualitative difference between the learning mechanisms of child and adult L2 learners. The hypothesis, as formulated in 1990, stated that the implicit learning mechanisms that operate in child language learning are no longer efficient in adult language learning and that domain-general problem-solving mechanisms are used instead, a position supported by DeKeyser (2000), who also predicted that adults would need high verbal analytic ability to succeed in L2 learning. Meisel (2009) further claimed that the fundamental differences in learning mechanisms between child and adult acquisition may already emerge in early childhood, earlier than the critical age range hypothesized by Bley-Vroman (1990) (i.e., end of teens), and only for certain grammatical properties.

Although alternative theories have been suggested (e.g., DeKeyser, 2007), there is evidence supporting that the capacity for implicit learning weakens, but does not disappear, by age twelve (Hoyer & Lincourt, 1998; Long, 2017, citing Janacsek, Fiser, & Nemeth 2012). In addition, the findings of experimental studies that have focused on adult learners' implicit learning of semi-artificial grammars (Rebuschat, 2008; Rebuschat & Williams, 2006, 2009; Williams, 1999, 2005) typically show 65 percent accuracy in implicit learning groups, versus chance performance in control groups. If the capacity for implicit learning weakens, this makes it possible for cognitive aptitudes for implicit learning to compensate for the loss in efficiency of implicit learning mechanisms. The decline in the efficiency of implicit learning mechanisms could have a greater impact on the acquisition of certain language features and, as a result, a relationship between the acquisition of these features and individual differences in aptitude for implicit learning would become apparent.

At the level of empirical research, providing evidence in support of implicit learning processes is challenging. If the evidence is based on learning outcomes (i.e., acquired knowledge measured during a testing phase of an experiment), these outcomes can be the result of implicit learning, explicit learning, or a combination of both. Alternative experimental paradigms such as the serial reaction time (SRT) have been proposed (Nissen & Bullemer, 1987) that allow measuring learning online (i.e., during the training phase) using reaction time data. Evidence of implicit learning may be also indirectly established by measuring the extent to which participants are aware of the acquired knowledge, in (semi-)artificial grammar learning studies, even though the existence of verbalizable knowledge does not necessarily imply that learning did not happen implicitly, since implicitly acquired language knowledge (e.g., one's native language) can become verbalizable to a lesser or greater extent. Finally, evidence of implicit learning may be also indirectly established by linking learning outcomes with selected cognitive aptitudes that were engaged in during the learning process, as suggested by DeKeyser (2012).

Behind the claim that there is an aptitude for implicit learning, lies the assumption that individual differences of this trait exist at the population level. However, according to Reber's earlier work (e.g., Reber, 1989, 1993), individual differences in implicit learning should be minimal, relative to individual differences in explicit cognition, due to the fact that implicit learning is evolutionarily older and reflects primitive cognitive systems. The issue of individual variation in implicit learning is of considerable theoretical and practical importance. Theoretically, Reber's (1993) evolutionary theory of implicit learning predicts that this type of learning preceded the development of explicit cognition, which did not develop until *Homo sapiens*. As a result, the theory predicts fewer individual differences than in conscious processes, which are more recent in terms of evolution, and a dissociation with performance on standard psychometric measures of intelligence, which engage explicit cognitive processes. Practically, if there is no variation in implicit learning, this means that the general population is homogenous in this regard and that implicit learning cannot covariate with or be meaningfully related to other variables. In his later work (e.g., Reber & Allen, 2000), however, Reber conceded that individual differences in implicit functioning do exist, based on empirical findings showing measurable differences in both implicit rule learning and incidental learning. The existence of individual differences solved the practical problem without affecting Reber's evolutionary theory, since any measurable differences in implicit functioning can still be predicted to be on a tighter distribution than differences in explicit functioning and to be largely independent from differences obtained on explicit measures.

Subsequent research in cognitive and educational psychology provided further evidence in support of the existence of individual differences in implicit learning. Kaufman et al. (2010) and Woltz (2003) both showed individual differences in implicit cognition and defended the idea that implicit learning is a cognitive ability. Kaufman et al. (2010) investigated the implicit learning of sequential patterns via the SRT procedure, an experimental paradigm where participants are asked to respond as quickly as possible to a series of nonverbal stimuli (e.g., asterisks) that appear at specific locations on a computer screen. The order of locations is either dictated by a complex set of rules or is a repeating sequence. In both cases, participants typically show a decrease in reaction times, suggesting that they have learned to anticipate the location of the stimuli. Kaufman et al. provided evidence of individual differences on a probabilistic SRT task as well as evidence of meaningful relations between performance on the SRT task and areas of complex cognition, such as verbal analogical reasoning and educational attainment in a variety of domains, including foreign language. They concluded that this was an area deserving further study. Woltz (2003) argued that individuals can be expected to differ in implicit cognitive processes, just as they differ on most cognitive measures, and provided evidence of individual differences in repetition priming (i.e., the ability to process stimuli faster without conscious guidance or intention when they are repeatedly presented) and semantic priming (i.e., the ability to make subconscious meaning associations). Woltz further suggested that the general domain of implicit cognitive processes could be a fruitful area in which to investigate new aptitude constructs, arguing that exploring individual differences in implicit learning could result in aptitude constructs that have minimal overlap with existing ones, which in general involve explicit, declarative processes.

These calls for new aptitude constructs in educational psychology (e.g., Woltz, 2003) and cognitive psychology (e.g., Kaufman et al., 2010) have led to a re-examination and re-conceptualization of language aptitude in the SLA field that departs from the old constructs of the first aptitude test batteries such as the MLAT. There is no doubt that implicit cognitive abilities constitute a fruitful area to investigate new aptitude constructs. There is no doubt either, as this Element will try to convey, that implicit cognitive abilities constitute a challenging area to investigate due to the elusive nature of implicit cognitive processes and to the fact that implicit cognitive abilities have failed to yield evidence of a unitary construct (e.g., Gebauer & Mackintosh, 2007; Siegelman & Frost, 2015).

This introduction has aimed at providing an overview of the key concepts surrounding the notion of language aptitude and the proposal that language aptitude includes cognitive abilities involving implicit processes, such as implicit learning and implicit memory, which are advantageous to learning an L2 without awareness. Sections 2, 3, and 4 of this Element will delve into the notion of implicit language aptitude and its measurement and provide a focused overview of relevant research studies investigating individual differences in implicit learning and memory and their role in L2 learning.

2 What Are the Key Readings?

2.1 Definition of Implicit Language Aptitude

Implicit language aptitude can be defined as those cognitive abilities that facilitate implicit learning and processing of an L2, understanding by "implicit" "in the absence of (1) conscious intention to learn, (2) conscious awareness of the fact that we are learning, and (3) conscious attribution of any noticed change to the effects of learning" (Jimenez, 2002, p. 62). Implicit cognitive abilities rely on selective attention (i.e., attention directed to the relevant dimensions of the input), but do not engage central executive resources like explicit abilities (see Table 1 for a comparison of implicit and explicit mechanisms on a number of dimensions). As Jimenez (2002) puts it, implicit learning "does not depend on the intention to learn or directly on the amount of attentional resources available, it crucially depends on whether learners selectively attend, or respond in any way, to the relevant stimulus dimensions" (p. 59). In other words, selective attention, but not executive attention, is required for implicit learning. Once stimuli are selectively attended, with relatively low-level perceptual attention, implicit learning can occur automatically without engaging any additional executive processing resources.

Table 1 Characteristics of explicit and implicit cognitive mechanisms (from MacDonald, 2008, p. 1013)

Implicit system	Explicit system
Not reflectively conscious	Conscious
Automatic	Controllable
Fast	Relatively slow
Evolved early	Evolved late
Parallel processing	Sequential processing
High capacity	Limited by attentional and working memory resources
Effortless	Effortful
Evolutionary adaptation or acquired by practice	Acquisition by culture and formal tuition

Proposals to include implicit cognitive abilities as part of language aptitude (Granena, 2013a; Linck et al., 2013) were made in an attempt to refine and expand the prevailing concept of language aptitude in SLA. These proposals were made following calls for new aptitude constructs in educational and cognitive psychology (Woltz, 2003; Kaufman et al., 2010). For decades, the understanding of language aptitude in SLA had been shaped by early aptitude test batteries such as the MLAT (Carroll & Sapon, 1959), the Pimsleur Language Aptitude Test Battery (PLAB; Pimsleur, 1966) and the Defense Language Aptitude Battery (DLAB; Petersen & Al–Haik, 1976). These batteries have in common the fact that they were developed for placement or selection purposes having predictive validity in mind. They also have in common the fact that they are biased toward measuring cognitive abilities in the explicit domain. These are abilities that depend on intentional processes that require conscious monitoring and that rely on executive functions such as shifting, updating, and inhibition, all centered in the prefrontal cortex, a late-developing area of the brain in terms of evolution. The cognitive abilities that have been most commonly measured as part of language aptitude, largely as a result of the influence of the MLAT, have been rote memory and language analytical ability, two abilities that predicted learning outcomes under popular teaching methods at the time the MLAT was created, such as the audio-lingual method.

Rote memory, or explicit associative memory, has been measured via paired associates learning tasks, which present a series of stimulus–response associations for participants to memorize. MLAT V measures this ability via twenty-four words in an unknown language with their corresponding English translations for participants to memorize in two minutes. Participants are then asked to provide the translation of the words. Language analytical ability has been measured via tests such as MLAT IV, Words-in-Sentences, which asks participants to identify the grammatical role of highlighted parts of sentences. Carroll (1962, 1981) made a distinction between the ability to recognize the grammatical function of a word (i.e., grammatical sensitivity) and the ability to induce the rules governing a set of language materials. However, Skehan (1989) considered both abilities different aspects of language analytical ability, an ability that can be considered to overlap with metalinguistic ability (Ranta, 2008) and with explicit inductive learning ability, since tests such as the Words-in-Sentences provide participants with data and guidance so that they focus on structural properties of language and derive their understanding of a grammatical feature.

As a result of the influence of the early aptitude test batteries, aptitude to learn a language meant being able to memorize and consciously reflect on linguistic structure. This view of aptitude was not aligned with how languages are learned under contemporary teaching approaches that adopt task-based or other experiential approaches (Long & Doughty, 2009). Approaches such as task-based language teaching (Long, 2017) emphasize meaning-based communication rather than formal aspects of the target language. These advances in the understanding of how languages are learned, together with advances in the fields of cognitive and educational psychology, led to the need to update the concept of language aptitude in the SLA field and to the development of new aptitude measures (i.e., the Hi-LAB; Linck et al., 2013) that included cognitive abilities from both the explicit and implicit domains.

As already brought up in Section 1 of this Element, claiming the existence of an implicit type of language aptitude raises questions regarding the possibility to learn an L2 implicitly, even in adulthood, and regarding the existence of individual differences in implicit abilities and their meaningful relationship with other factors, including language learning outcomes. As for the possibility to learn implicitly, much of the foundational experimental work on this topic can be attributed to the pioneering research of Arthur Reber (e.g., Reber, 1993). The earliest studies on the acquisition of complex patterns without awareness were conducted in the 60s using artificial grammar learning experiments (e.g., Reber, 1969; Reber & Millward, 1965, 1968). These experiments showed that adult participants developed some sensitivity to the constraints of the grammar through exposure to exemplars and that they were able to acquire patterns of sequential dependencies. Implicit learning was seen as a “generalized, domain-free inductive process that derives information about patterned relationships in the stimulus environment, and represents these relationships in an abstract and tacit form” (Winter & Reber, 1994, p. 117). In the SLA field, this line of research has inspired the work by N. Ellis (e.g., Ellis, 1996) and the claim that L2 acquisition is driven by sequence learning or chunking, a type of learning that is highly sensitive to items that co-occur at greater than chance levels in the input. According to this view, learners progress from the use of memorized formulaic phrases through slot-and-frame patterns to more open grammatical constructions (e.g., Ellis & Cadierno, 2009). Other experimental studies that have focused on adult learners’ implicit learning of semi-artificial grammars (Rebuschat & Williams, 2006, 2009; Williams, 1999, 2005) typically show 65 percent accuracy in implicit learning groups, versus chance performance in control groups. These findings suggest that the capacity for implicit learning is not lost in adult learners (see, e.g., Long, 2017), even though it deteriorates and weakens with age (Hoyer & Lincourt, 1998; Janacsek, Fiser, & Nemeth, 2012). Although there is evidence of implicit learning in the literature, there is risk of certain circularity in the definition of a so-called implicit language aptitude (i.e., *petitio principii*), since what is to be proved is already assumed in the premises, thus creating a circle in reasoning. Effective measures of implicit cognitive abilities are needed, as well as validation studies of available measures.

A well-known challenge that implicit learning studies have to face when they rely on learning outcomes (i.e., acquired knowledge) is that these outcomes can be the result of implicit learning, explicit learning, or a combination of both. As the *polarity fallacy* referred to by Reber (1993) says, one should not treat implicit and explicit learning as completely independent, since they complement each other and cooperate. They are not all-or-none processes, but graded processes. Defending the existence of implicit learning does not deny the interaction between learning and consciousness or the fact that learning can lead to the adoption of explicit strategies. Even the fact that knowledge can be verbalized does not necessarily imply that learning did not happen implicitly, since implicitly acquired language knowledge (e.g., one's native language) can become verbalizable to a lesser or greater extent. In the end, the notion of learning is precisely distinguished from the broader concept of adaptation because it operates on cognitive representations that are accessible to consciousness (Jimenez, 2002). Experimental studies can, nevertheless, balance explicit and implicit elements. They can also rely on online measures of learning and provide indirect evidence of implicit learning either by measuring the extent to which participants are aware of the acquired knowledge or by establishing a relationship between learning outcomes and cognitive aptitudes (DeKeyser, 2012).

Regarding the existence of individual differences in implicit abilities, Reber (1993) hypothesized that there should be little individual variation, and less than in explicit processes, due to the fact that implicit learning mechanisms are evolutionarily older and, therefore, more robust. The assumption that implicit learning is characterized by a tight distribution at the population level has, however, been challenged by research showing that individual differences in implicit memory and learning do exist. For example, Woltz (1990a, 1990b, 1999) demonstrated that implicit memory measures of priming had reliability estimates high enough (internal consistency > 0.60) to suggest measurable individual differences. In addition, these individual differences do have correlates in other spheres of cognition and personality. As a result, implicit cognitive processes can be considered abilities with meaningful individual differences. As for the cognitive correlates of implicit learning ability, Kaufman et al. (2010) reported a significant correlation with processing speed, but no relationships between implicit learning and general intelligence scores, intentional associative learning, or working memory. Similarly, Woltz (1990a, 1990b, 1999) found