Implicit learning, development, and education

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Introduction

The present chapter focuses on implicit learning processes, and aims at showing that these processes could be used to design new methods of education or reeducation. After a brief definition of what we intend by implicit learning, we will show that these processes operate efficiently in development, from infancy to aging. Then, we will discuss the question of their resistance to neurological or psychiatric diseases. Finally, in a last section, we will comment on their potential use within an applied perspective.

The fundamental role of learning, once neglected by cognitive psychologists a few decades ago, is now acknowledged in most areas of research, including language, categorization and object perception (2). Of course, nobody has ever claimed that language development is independent of infants' experience. However, the dominant Chomskian tradition has confined learning to subsidiary functions, such as setting the values of parameters in a hardwired system. Recent work shows that fundamental components of language such as word segmentation (69) can be learned in an incidental way similar to that involved in the acquisition of other human abilities. Likewise, it has never been denied that learning plays a role in categorization and object perception, but acquisition processes were thought to be limited to new combinations of preestablished features (7). However, Schyns and Rodet (77) have shown that elementary features can themselves be created with experience (for a review, see 74, 75).

The type of learning process that receives the most attention in the current literature relates to implicit learning. Different definitions of implicit learning have been proposed (63, 4), most of which involving the idea that implicit learning contributes to the formation of an implicit knowledge base, dissociated from explicit knowledge (see 76, for a review subscribing to this view). We propose a definition that is neutral with regard to the issue of the nature of the resulting knowledge. In our view, implicit learning covers all forms of unintentional learning in which, as a consequence of repeated experience, an individual's behavior becomes sensitive to the structural features of an experienced situation, without, at any time, being told to learn anything about this situation and without the adaptation being due to an intentional exploitation of some pieces of explicit knowledge about these features (58). Although there is little consensus within the literature, these two components – the behavioral sensitivity to the structure of the situation and the lack of intentional causes for this sensitivity – have been included in virtually all definitions of implicit learning (11, 65).

Many contributors to this area have added additional criteria. For instance, several researchers emphasize the point that explicit knowledge about the training situation is lacking or at least limited. Including this property in the implicit learning concept is obviously possible, insofar as terminology issues are arbitrary, but, as a matter of fact, doing so may well make the very existence of the phenomenon controversial (73). The exclusive reliance on a lack of intentional exploitation of explicit knowledge, on the other hand, makes the existence of the phenomenon "real" at the phenomenological, introspective level, and it is confirmed by a large number of experimental investigations. In our view, this type of learning is based on the action of unconscious processes, basically associative learning processes that progressively transform the individual's behavior, without noticing this transformation (59, 60).

Most of the studies in implicit learning area of research are laboratory studies run with adults. A prototypical paradigm in implicit learning is the artificial grammar paradigm (62). In this paradigm, participants are usually exposed to a subset of grammatical strings generated by a finite-state grammar, where the strings can be composed of printed consonants for instance. The grammar defines the transition rules between events. Participants are then tested to see whether they can discriminate between new grammatical and non-grammatical strings. The results show that participants recognize grammatical strings at a significantly above-chance level, as if they had discovered the rules of the grammar. We suggest that, through the action of unconscious processes, the participants develop, in the course of the training phase, a behavioral sensitivity to the structure of the situation so that they become "familiar" to the "look" of the grammatical strings, whether these strings have been specifically seen during training or not (new grammatical strings). This feeling of familiarity does not require possessing any knowledge about the genuine structure of the strings. Implicit learning shapes the perceptions a participant develops of a situation through the direct and continuous tuning of the processes devoted to the treatment of incoming information. These processes provoke changes in the way information is encoded, and these changes directly affect the participant's phenomenal experience (61, 59). We will turn to this interpretation later in the chapter.

Implicit learning processes in development

Examining the characteristics of the experimental situation usually involved in this field of research helps to understand why implicit learning is, a priori, relevant for development. First, implicit learning is generally observed while participants are not asked to discover the structure of the situation they are confronted to. Instead, participants are generally instructed to engage in any activity ensuring attentional processing of the training display but diverting them from tacking an analytical approach. Second, only well-structured patterns are displayed. For instance, in the artificial grammar paradigm, only positive instances of the material to be learned (i.e., only grammatical strings) are shown to the participants during training. As we will discuss later, this characteristic is a prerequisite for incidental conditions of learning because showing errors or negative instances of a rule, for instance, may well cause a shift within the learner toward adopting a problem-solving attitudinal set and/or may cause interferences that are detrimental to learning. The third characteristic of implicit learning situations is their relative complexity. It has been shown that participants are able to learn implicitly highly complex material that they would not be able to easily learn explicitly. Thus, on the whole, the implicit learning conditions are close to most real-life situations encountered by children or adults during their life. Implicit learning processes are indeed thought to be fundamental throughout life, supporting continuous behavioral adaptation to changing environmental conditions (65, 34).

Clearly, a large proportion of the motor, perceptive, and cognitive acquisitions made by children in the course of development result from learning, and more specifically from implicit learning processes. Implicit learning has been seen as responsible for at least some aspects of first-language (9) and second-language learning (8), category elaboration, reading and writing acquisition (56), adaptation to the physical constraints of the world (41), and acquisition of social skills (65). Most of this learning takes place during infancy and childhood, and constitutes the essential core of what a newborn must acquire to become an adult. This is why the idea of the primacy of implicit learning processes, initially claimed by Reber (65), has been by and large tacitly adopted by most authors working in the implicit learning domain. However, clearly, implicit learning processes do not operate only during infancy or childhood but are responsible for the continuous behavioral adaptation of humans during their entire life, as we will show it.

Developmental psychologists also consider that implicit learning processes play an important role in development. Karmiloff-Smith's model (38) postulates that the first phase achieved in each domain of competence corresponds to a level of behavioral mastery involving implicit knowledge, formed by data-driven processes. Explicit knowledge would be developed during a second phase through the action of an endogenous process of representational redescription. The distinction between implicit and explicit knowledge is present in several other developmental models (for a review, see 45) and appears to be basic to developmental studies of memory (36). Moreover, highlighting the fundamental role of bottom-up processes, as can be observed in the dynamical theories (82) or in connectionist modeling (16, 51), also attests to the major interest that developmental psychologists attribute to implicit learning processes in the formation of new adaptive behavior.

However, despite this role given to implicit learning processes, the developmental literature on this domain remains sparse. Moreover, nothing clear is known about the possible age-related specificity of implicit learning processes. Reber (65) has made the assumption that these processes are age independent, but the results of the current studies appear contradictory in this respect.

Implicit learning processes in infancy, childhood, and aging

Gomez and Gerken (24) used the classical paradigm in implicit learning of the artificial grammar paradigm (62), with infants aged approximately 12 months. To adapt this approach (see above) for use with infants, Gomez and Gerken's study used auditory syllables instead of printed letters. These syllables were combined according to the rules of an artificial grammar to form legal sequences that were repeated several times during training. Infants were tested with familiar or new legal sequences, and illegal sequences. The results showed that the infants displayed longer orientation times toward familiar or new legal strings than toward nongrammatical strings, suggesting that they became sensitive to at least some aspects of the structure of the training set. Note that this study not only demonstrates that the implicit learning of an artificial grammar is efficient at a very early age but also suggests that these learning processes are probably involved in language acquisition. A similar conclusion can be achieved from a study of incidental learning of word segmentation conducted by Saffran *et al.* (69). Saffran, Johnson, Aslin, and Newport (68) have shown that eight-month-old infants are able to use the same learning mechanisms to segment sequences of nonlinguistic stimuli. The efficiency of implicit learning processes early in development (four to five years) has also been revealed in two other studies, one performed by Lewicki (43) and one by Czyzewska *et al.* (1991), quoted in Lewicki, Hill, and Czyzewska (44). More recently, two-year-old children have been shown to be successful in learning implicitly a sequence of spatial locations (5).

With regard to older children, Meulemans, Van der Linden, and Perruchet (50) compared the performance of children aged 6 to 7 years and 10 to 11 years and adults in an implicit learning task. They used the classical serial reaction time task (53), where participants had to respond as quickly as possible to the appearance of a target at one of four locations on a screen by pressing one of four keys corresponding to the position of the target. Without them knowing it, participants were shown a repeating sequence of target appearances, with some intermixed random trials. Regardless of age, reaction times improved on the repeated sequence when compared to the random parts, thus demonstrating that six-year-old children learned the sequence as well as adults did. Moreover, children and adults improved their performance on the same parts of the sequence, a finding that gives additional support to the claim that implicit learning is age insensitive. A study performed by Roter (1985), quoted in Reber (65), also confirms this view. No age-related differences in an artificial grammar task were obtained in connection with implicit performance in children aged 6 to 7 years, 9 to 11 years, and 12 to 15 years.

However, contradictory results are provided by Maybery, Taylor, and O'Brien-Malone's study (47), which was directly inspired by Reber's assumptions (65) of age independence. These authors compared two groups of children, one aged 5 to 7 years and the other one aged 10 to 12 years. An incidental covariation task adapted from Lewicki (43) was used, where children had to learn a covariation between the location of a picture in a 4 ∞ 4 matrix and two other features, the side from which the experimenter approached them and the color of the matrix board and cover. After training, 10- to 12-year-old children were better at guessing the location of the pictures in a subsequent test phase than were 5- to 7-year-olds. Moreover, the performance displayed by the younger children was not above chance, indicating that these children did not implicitly learn the covariations. A few age-related differences are also reported in a serial time reaction task in children and adolescents under incidental learning condition, although these differences were much higher and systematic under explicit learning condition (37).

To sum up, the literature reports contradictory results with regard to the age independence of implicit learning processes. Mayberry and O'Brien-Malone (46) consider that empirical evidence for this assumption is up to now limited. One possible explanation is that the age effect observed in the Mayberry, Taylor, and O'Brien-Malone's study was due to a contamination effect of explicit knowledge on performance in the implicit task. The intentional exploitation of explicit knowledge can never be totally ruled out in classical implicit learning paradigms (73). Also, of course, if such explicit factors intervene during implicit learning, a global age effect can be expected in performance improvement. It thus appears crucial to use a method avoiding any contamination effect. To this end, Vinter and Perruchet (84) developed the "neutral parameter procedure," which had been devised to minimize the intervention of explicit influences on performance. This procedure is based on two criteria. The task demands criterion requires that instructions lead participants to focus on behavioral components other than those on which the unconscious influences are assessed, and the neutral effect criterion stipulates that unconscious effects must be assessed on the basis of a behavioral parameter that is neutral with regard to task achievement. Applying this procedure, Vinter and Perruchet (85) have shown that children between the ages of 4 and 10 years are able to modify implicitly their usual drawing behavior, without them aiming at this change. More important with respect to the topic discussed here, no age-related differences appeared in these experiments run with the "neutral parameter procedure." For the authors, it means that implicit learning processes are age independent, as claimed by Reber (65), but age effects are likely to appear as soon as explicit influences can intervene on the participant's performance. Other factors may cause the emergence of age-related differences, as clear from the literature on implicit learning in aging.

Indeed, the postulate of age independency appears to be more controversial with respect to aging. On the one hand, equal amounts of implicit learning were found when young and old people were compared in several studies (21, 28, 29, 72). No age-related decline in performance was reported in a recent study where old participants were asked to learn letter strings with a given letter always appearing at the same position (31). Young and old adults learned implicitly this regularity equally well. The authors demonstrated that learning occurred during the encoding phase. This study, and others, testifies for the preserved capacity of older people to adapt efficiently to environmental regularities.

On the other hand, a decline in implicit performance was revealed in other studies when complex learning material was used or when low-ability elderly people were tested (10, 12, 32, 30). French and Miner (21) demonstrated that age differences between young and old participants emerged in implicit learning when a dual-task condition was used but not under a single-task condition. The same conclusion was achieved in a more recent study by Nejati *et al.* (53), who showed that implicit learning in elderly adults was affected by an increased attentional load introduced by a condition of dual-task interference. Age-related deficits were also observed within a restricted age range, when elderly individuals of different ages were compared in a complex task (32). This study, which contrasted young-old (65- to 73-year-old) and old-old (76- to 80-year-old) people, revealed a decline in implicit learning performance within aging itself. However, older adults seemed to remain sensitive to highly complex sequential regularities, although they learned those less than younger adults (3).

Howard and Howard (32) suggested that processing material with high-level structure places high demand on working memory, which is known to decline with aging (71). Indeed, they reported a significant positive correlation between working memory span and both speed and accuracy of implicit learning. These authors appealed to the concept of the simultaneity mechanism of cognitive aging developed by Salthouse (70) to account for this result. The more complex the material to process is, the more events people have to keep activated simultaneously in their working memory in order to learn how they relate to one another. A decline in working memory capacity should therefore provoke deficits in implicit learning tasks when they are structured at a complex level. It is this decline that might account for the age-related differences observed in implicit learning between young and old people as well as between young-old and old-old people.

It could be argued, however, that these age effects are at least partly due to the difference of timing in overt performance between young and old people, old people showing a global slowdown in their responses to stimuli, whatsoever. Howard, Howard, Denis, and Yankovich (33) have thus built an implicit learning situation where event timing mimicked that experienced by older adults in this situation and have confronted young adults to such slowdown implicit learning condition. Their results indicated that these artificially "aged" young adults still learned implicitly in a complex situation, but both performed lower than young control adults and better than old control adults. The pattern of performance deficits displayed by old adults still appeared different from that observed in the "aged" young adults. These results rule out the idea that event timing alone may be responsible for the age effects shown in old people, when they learned implicitly from complex situations.

To sum up, implicit learning processes operate efficiently all along life, ensuring the progressive and continuous adaptation of human behavior to the environment. These processes are globally not sensitive to age effects, although clear limits in this age independency postulate seem to appear. The more demanding in attentional cognitive resources a learning task is, the more complex the information to be learned is, and the more permeable to explicit influences the learning procedure is, the more likely age-related differences are to emerge.

Implicit learning processes and pathology

Considering that, from the phylogenetic viewpoint, the implicit mode of learning precedes the explicit mode, Reber (64, 65) claimed that implicit learning should be independent of IQ and should be able to withstand neurological or psychological damage.

The question of IQ independency

The literature supports globally the IQ-independence postulate. Reber, Walkenfeld, and Hernstadt (66) found a nonsignificant correlation between IQ and implicit performance in an artificial grammar task in young adults, while significance was reached when IQ was correlated with an explicit learning performance score. The same conclusion was proposed by Myers and Conner (52) in a computer-control task and by McGeorge, Crawford, and Kelly (48) in an artificial grammar task. The independence of implicit learning with psychometric intelligence has been proved in an impressive study carried out by Gebauer and Makintosh (23) on a very large sample of participants. These authors failed to report any significant correlations between various measures of intelligence and different measures of implicit learning performance. However, this study was not concerned with persons with low IQs.

Using a covariation task, Maybery, Taylor, and O'Brien-Malone (47) did not find any relationship between IQ and implicit performances in children with an average age of 6 to 11 years and divided into low IQ (78 to 97), medium IQ (100 to 110) and high IQ (110 to 125) groups. They reported that implicit learning improved with age and that explicit learning, assessed through a task presenting a logical structure similar to the implicit task, improved with age and with intelligence. Atwell, Conners, and Merrill (1) also compared the impact of implicit and explicit learning in individuals with intellectual disability, with IQs varying only from 50 to 75, using an artificial grammar learning paradigm. Their conclusion agreed with Reber's postulate that implicit learning is largely preserved in intellectually disabled persons.

However, this conclusion has been challenged by Fletcher, Maybery, and Bennett (20), who compared a group of gifted children aged 9 to 10 years (IQ of around 120) with a group of mentally retarded children (IQ of around 60) using a task where participants had to learn implicitly a covariation. Implicit performance was below chance in intellectually disabled children and above chance in the gifted children. These results suggest that implicit learning processes might be inoperative in children with mental retardation. But this negative result may again be due to the fact that explicit influences have contaminated the children's performance in the learning task. Indeed, adopting the neutral parameter procedure suggested by Vinter and Perruchet (84) in a task where participants are incidentally led to modify their graphic behavior, Vinter and Detable (86) have shown that the impact of implicit learning was not a function of IQ in adolescents with IQs varying from 30 to 70.

The question of resistance to neurological or psychological damages

The robustness of implicit learning processes has been assessed in regard to various kinds of neurological and psychological or psychiatric diseases. It is out of the scope of this chapter to review this literature; we will just give a brief overview of the main results.

It was of course very tempting to investigate whether amnesic patients are still able to learn implicitly because learning can hardly be dissociable from memory, and contamination of performance by explicit influences can hardly be suspected in these patients. A large body of research conducted with amnesic patients concerns implicit sequence learning. Globally, their capabilities to learn implicitly sequences are shown to be preserved, whether Korsakoff's or Alzheimer's patients are considered (54, 55, 17, 39). This result demonstrates that implicit sequence learning does not require the brain areas that are necessarily involved in explicit memory. However, implicit performance was sometimes superior in controls than in amnesic patients (54) but not systematically at a significant level (67). It has been suggested that amnesic patients may encounter more difficulties than controls when higher order of information has to be learned (13), although again they did learn such complex information (12). However, this issue remains controversial. In a sequence learning paradigm, Vandenberghe, Schmidt, Fery, and Cleeremans (83) recently showed that amnesic patients learned a sequence that followed deterministic rules but not probabilistic ones, while control participants succeeded in both sequence structures.

The investigation of implicit learning processes in patients with Huntington's disease or with Parkinson's disease (PD) reveals that implicit sequence learning may be partly damaged in these patients (17, 35). These results are not clear cut; however, only a third of the patients with Huntington's disease tested by Knopman and Nissen (39) did show impaired performance. Siegert, Taylor, Weatherall, and Abernethy (79) carried out a meta-analysis of a series of studies run with PD patients, and that have investigated implicit sequential learning. Their conclusion was that implicit sequence learning appears to be impaired in these patients. What aspects of performance are more precisely impaired? Seidler, Tuite, and Ashe (77) revealed that PD patients did not fail to learn implicitly sequential information, but that they were impaired in managing to translate sequence knowledge into rapid motor performance. This conclusion may suggest that at least part of the deficits shown in PD patients may come from the use of overt motor responses in these implicit learning tasks. Indeed, Smith, Siegert, and McDowall (81) did not report any differences between PD patients and controls when tasks involving verbal responses were used, such as an artificial grammar task or a verbal version of the serial reaction time task. Other studies converge in reporting rather intact implicit learning capacities in PD patients in an artificial grammar task (49, 87). However, when the learning procedure included a trial-by-trial feedback, the PD patients exhibited deficits in category learning task (80), as well as when a complex relationship between stimulus dimensions was used to define category membership in an implicit category learning task (19). In summary, this literature tends to confirm that the implicit learning processes are globally preserved in patients with Huntington's disease or with PD, as long as the task does not rely too strongly on overt motor responses and on integrative processes, and possibly does not require processing too complex information.

A growing body of research is devoted to the study of implicit learning processes in psychiatric diseases, in particular in schizophrenic patients. The conclusions that can be drawn from this literature are very similar to those mentioned in the previous areas of research. On the one hand, implicit learning processes appear to be intact in patients with schizophrenia at least when assessed with an artificial grammar learning task (14, 27). On the other hand, a moderate impairment of their performance in serial reaction time tasks has been recently confirmed by Siegert, Weaterall, and Bell (78), who performed a meta-analysis of results collected in more than 200 patients. These tasks are usually based on visuospatial cues. When nonspatial sequences are introduced, a smaller learning effect is still observed in patients with schizophrenia in comparison to healthy controls, although both groups do display learning. Thus, the moderate deficit shown in these patients in regard to sequential learning could be due to a minor sensitivity to regularly occurring sequences of events in the environment.

In sum, the current literature provides a global support to the postulate expressed by Reber (65), stipulating that implicit learning processes are resistant to both neurological and psychiatric diseases. Differences with control participants may, however, emerge, depending on the type of tasks used, on the type of responses measured and possibly on the complexity of the material to be learned.

Implicit learning processes and education or reeducation

This last section will examine whether the demonstration that implicit learning processes are relatively robust to age and pathology may open new ways to approaching educational or reeducational methods. It is, however, important to point out that such a section can only be speculative because of a global lack of systematic researches carried out within such an applied perspective. We will also limit our speculative considerations to the educational (scholastic) domain, with the hope that some reflections are general enough to be extended to broader preoccupations related to remediation in diverse pathological contexts.

Implicit learning processes outside of laboratory

To provide support to the view that implicit learning can constitute an interesting way to approaching education or reeducation, it is pertinent to show that this mode of learning contributes naturally to human development, that is, out of laboratory, although the body of research devoted to this question is not large. The only domain in which a sizeable amount of literature has emerged concerns the relationships between implicit learning and oral or written language acquisition (25). The practical applications of implicit learning appear to be still sparser. Some methods have evolved that exploit principles that can be a posteriori related to implicit learning principles, such as using conditions as similar as possible to natural learning to reach second language or reading (26, 40). An extensive literature also concerns the use of errorless learning for reeducative purposes in a neuropsychological perspective (see 18). The explanations for this relative paucity are certainly manifold. One of the most important may be that learning in real-world situations most often involve some mixture of implicit (or incidental) and explicit (or intentional) learning. Similarly, for reeducative purposes, a mixture of incidental and explicit learning is possibly preferable because behavioral acquisitions obtained through implicit learning processes do not contribute to knowledge formation as explicit learning processes do. This point warrants to be made clearer.

Our own understanding of how implicit learning processes operate has been developed in details elsewhere (59, 60). A few points are nevertheless worth mentioning in order to facilitate the understanding of how we conceive of the potential interest of implicit learning for (re)educational procedures. Implicit learning occurs whenever we can suspect that unconscious processes have led to participant's behavioral modifications, such that these changes reflect the structural characteristics of the situation with which the participant repeatedly interacts, without intentionally looking for such an adaptation. It is from the direct interactions between some properties of the subject's attentional and memory systems (more precisely, a limited attentional focus size, a tendency to associate automatically elements that enter together in a same attentional focus, and a tendency for memory traces to be subject to reinforcement, forgetting, and interference) and some structural properties of the material to be learned (for instance, their statistical distribution) that the progressive behavioral adaptation emerges. In other words, implicit learning does not lead, in our view, to the acquisition of unconscious knowledge about the structural characteristics of the learning situation. Instead of developing (unconscious) knowledge about the learning situation, implicit learning processes directly shape the participant's behavior and concomitant phenomenological apprehension of the situation, thanks to the formation of cognitive units that progressively become isomorphic to the structure of the situation. In an artificial grammar learning task, for instance, the participants would not unconsciously abstract the unknown grammatical rules that structure the material they are confronted with, but would become progressively sensitive to the structural features of this material, such as its statistical properties and its salient features. The more salient a feature is, the more likely it can draw attention and consequently create a memory trace that shapes the individual's phenomenological experience. Furthermore, the more frequent this feature is, the stronger its memory trace is consolidated. In our view, these basic functional laws of attention and memory, in interaction with the specific properties of the material to be learned, account for the progressive adaptation of the participant's behavior to the rules of the grammar (or to the products of the rules), without any need of abstracting the rules themselves.

Thus, if the educator or reeducator aims at helping subjects to acquire rule-based knowledge about a precise situation, methods based upon implicit learning processes would not be appropriate. But if the objective is to help subjects to develop adapted behaviors to their environment, these methods are of interest, according to us.

We propose to examine now how to build a learning situation based on implicit processes.

A rationale for building implicit learning situations

Considering our understanding of how implicit learning processes operate both inside and outside laboratory, we can try to delineate what are the main characteristics that learning situations have to present in order to elicit at best these processes. In some way, this turns out to build a rationale for designing any learning situation that aims at eliciting implicit processes.

During the learning phase, the participant must be confronted only to positive instances of the rule or of the regularity (or of the behavior) that have to be learned. Including errors (or counterexamples of the regularity) in the material manipulated during learning must be avoided. This condition contrasts with more classical learning situations such as those used by teachers at school, where the students are, for instance, required to identify grammatical errors in a text or to select the good response among three false ones. These types of exercises aim at testing whether the student is able to correctly apply and generalize a rule that has previously been explicated. In an implicit learning approach to the question of orthographic acquisition, the participant would be directly confronted with a series of positive instances of the rule (the difficulty in this case would be to imagine a task that obliges the participant to process attentively all the orthographically well formed sentences several times). The repeated exposition to such a structured material will elicit associative processes so that the elements that enter together into an attentional focus will be associated. However, these associative processes are rather blind, and they function whether the material contains errors or not. It is for this reason that introducing errors into the material may have detrimental effects on learning: The learners may become familiarized as much with false as with correct associations. This point can be illustrated indirectly by an anecdotal observation. An interesting spelling error can be observed in French researchers who are familiar with the English language, when they write the French word *adresse*. This word is often spelled *addresse* because of the repeated confrontation with the English spelling of the same word. Similar negative effects of the exposition to errors in relation to spelling or other abilities have been shown in the literature (6, 15, 22, 57). The success of the use of errorless learning methods for reeducative purposes also testifies for the value of an approach founded on the withdrawal of the confrontation to errors (18).

A second important feature of implicit learning tasks is the fact that the regularity or the rule that is of interest must be "isolated" at best. We have pointed out the important role played by attention in the formation of the associations between the material's elements, these associations constituting the substance of the learning processes. However, the child's or adult's attentional focus is limited and cannot capture a large number of elements together. Moreover, this focus is constrained in time and in space, and the elements to be associated cannot be too distant or separate, whether time or space is considered. Indeed, the possibility to establish an association decreases rapidly when the distance between elements increases (11). For these reasons, it is better to isolate the regularities of interest in the learning situation. We can again give an indirect illustration to this point, showing that when regularities occur within a limited space and time, they provoke the formation of automatisms that express themselves even if they do not correspond to an adapted behavior. An illustration can be found in some aspects of orthographic acquisition, such as how to mark the plural of nouns. Consider the following few examples of French expressions that a child may read in a text: *il cher-*

che ses clés (he's looking for his keys), *tu prends tes jouets* (you take your toys), and *elle coupe des fleurs* (she's cutting flowers). The association between the "s" at the end of the article and the "s" at the end of the noun is regular and frequent, and it occurs within a reduced space and time, rendering their association into a same attentional focus very likely. This association is consolidated through experience and can form the basis of an automatism. This is suggested by the work of Largy *et al.* (42). They asked French university students to recall sentences by writing them down. These sentences included homophonous words such as *asperge*, which means "to sprinkle" as a verb and "asparagus" as a noun. To increase task demands, participants were also asked to memorize nouns and to write them down when they had finished writing the sentence (on another page so that they could not correct possible misspellings). The target sentences were sentences such as *L'éléphant voit les clowns et il les asperge* ("The elephant sees the clowns and sprinkles them"). French children and adults tended to add –*s* more or less systematically at the end of *asperge*, as if it were a noun. Erroneous addition of –*s* increased even further when the personal pronoun *il* in the sentences stood for a noun that lexically primed the nominal form of a noun-verb homophonous pair. For example, *il* in the sentence *Le jardinier sort les legumes et il les asperge* ("The gardener takes the vegetables out and sprinkles them") refers to the "gardener" who is related to the homophonous noun form "asparagus," but *il* refers to a word that primes the verbal form of *asperge* in the sentence *L'éléphant voit les clowns et il les asperge* ("The elephant sees the clowns and sprinkles them"). These errors can be seen as a product of the action of unconscious associative processes that have easily captured the association between the article (plural) and the noun (plural), thanks to their close occurrence in time and space, the unit *les asperges* (the asparagus) being furthermore much more frequently encountered than the unit *les asperge* (sprinkles them).

Thus, in order to facilitate the attentional capture of the relevant elements that must be associated, it is better to withdraw from the learning situation all elements that may make less salient the to-be learned association and could attract the participant's attention.

A third important characteristic of a learning condition based on implicit processes is the fact that the material to be learned must be repeatedly presented to the learners. Associations take time to emerge, and this is why the repetition of the presentation of the learning condition is crucial. The number of repetitions, the number of learning sessions, and their mode of presentation (distributed or not for instance) depend on several factors and cannot probably be determined with security in advance. This uncertainty, as well as the fundamental role of time, may contribute to increase the difficulty of relying on implicit learning processes in an applied perspective. Reeducating through implicit learning processes requires time, probably more time than explicit methods would need.

Finally, the last feature that we would like to point out is related to an important aspect of the very definition of implicit learning. The learning condition must be designed so that the learner is brought to process attentively the relevant information without making explicit at all what he or she is supposed to learn. For instance, if one aims at developing in children a behavioral sensibility to some orthographical rules, the person can imagine to ask them to spell out words, without never mentioning the rule that is of interest. Spelling out words requires an attentional processing of the words, which is a prerequisite for capturing any regularity occurring in these words (and of course, a rule provokes inevitably regularities at the material's surface).

Conclusion

In conclusion to this chapter, it is probably important to point out that our proposals concerning the use of implicit processes for educative or reeducative purposes should be taken with caution. Clearly, the gap may be large between, on the one hand, general learning principles that globally apply to human behavior and, on the other hand, specific reeducational methods that should be dedicated to specific human behavioral disorders. Furthermore, implicit learning processes shape the individual's behavior in resonance with the structure of a learning situation but do not lead to any explicit knowledge of this very structure. For instance, if one aims at teaching orthographical rules, implicit learning processes would not be appropriate to this scope because they can only develop in individuals a behavioral tendency to adapt to the frequent and salient regularities that reflect the rules. Consequently, the performance cannot attain perfection (as would be the case if one would apply the rules), and it is permeable to errors each time a frequent association enters in conflict with a much less frequent association displaying another rule, as we have seen it before with our example of article-noun plural rule. However, we do believe that testing whether implicit learning processes may provide even partial solutions for remediation is worth trying.

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