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THE ROLE OF MORPHO-PHONOLOGICAL REGULARITY AND SIMILARITY IN PROCESSING ITALIAN VERBS

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Prefazione

L'obiettivo di questo studio sperimentale è quello di indagare i meccanismi di rappresentazione ed elaborazione delle forme verbali regolari, irregolari e sub-regolari dell'italiano. In psicolinguistica, il dibattito sull'elaborazione dei verbi regolari e irregolari è basato sull'opposizione tra modelli a "Doppio Meccanismo" (Pinker e Prince, 1988; Clahsen, 1999; Caramazza, Laudanna e Romani, 1988), che affermano che le forme regolari vengono elaborate tramite l'applicazione di regole flessive, mentre le forme irregolari vengono recuperate come parole intere dalla memoria associativa, e modelli Connessionisti (McClelland e Patterson, 2002; Joanisse e Seidenberg, 1999; Rumelhart e McClelland, 1986), che sostengono che un singolo meccanismo associativo renda conto dell'elaborazione di forme sia regolari che irregolari.

Nonostante i modelli a Doppio Meccanismo sostengano meccanismi di rappresentazione nettamente distinti per verbi regolari e irregolari, diversi studi in letteratura sottolineano come questa opposizione sia messa in

discussione dall'esistenza di famiglie di verbi "sub-regolari", che condividono caratteristiche morfo-fonologiche e seguono lo stesso *pattern* flessivo.

Il dibattito sui *pattern* sub-regolari si è sviluppato soprattutto attorno a lingue come l'italiano, basate sulla suddivisione in classi flessive, ognuna caratterizzata da uno specifico paradigma regolare, e su una mutevole aggregazione di famiglie sub-regolari.

La coesistenza di *pattern* regolari multipli e di famiglie sub-regolari sembra essere coerente con la teoria dell'Ottimalità (Prince e Smolensky, 1993; Benua, 1997; Bernhardt e Stemberger, 1998; Smolensky, 1999), che si distacca dal concetto tradizionale di regola flessiva e invoca il ricorso a vincoli fonologici, basati su analogie fonologiche tra forme superficiali di parole e su diversi gradi di importanza e "violabilità".

Nel presente studio sono stati condotti esperimenti di riconoscimento e produzione di forme flesse di verbi reali regolari, irregolari e sub-regolari appartenenti alle tre classi flessive dell'italiano, e sull'elaborazione di pseudo-forme verbali. Gli esperimenti di decisione lessicale (1-7) sono stati realizzati allo scopo di testare la possibilità: 1) che l'attivazione di un *pattern* regolare fosse ostacolata dall'attivazione concorrente del modello sub-regolare caratteristico di uno o più verbi

morfo-fonologicamente simili, e 2) che l'attivazione di un *pattern* sub-regolare fosse inibita dall'attivazione concorrente di un paradigma flessivo regolare. Questa ipotesi è stata verificata attraverso l'impiego di pseudo-forme flesse basate su radici sub-regolari morfo-fonologicamente simili a verbi regolari, combinate con un suffisso flessivo regolare, e su radici regolari combinate con il suffisso flessivo di un verbo sub-regolare morfo-fonologicamente simile. Ciascuna lista di pseudo-parole è stata impiegata in compiti di decisione lessicale con *priming* (nei quali le pseudo-forme venivano precedute dall'infinito del verbo modificato) e in compiti di decisione lessicale semplice, allo scopo di testare eventuali effetti inibitori sia in contesti che pre-attivassero la radice verbale, sia attraverso la presentazione della pseduo-forma isolata.
Negli Esperimenti 1 e 2 sono stati impiegati pseudo-participi passati di verbi di 3° coniugazione. Negli Esperimenti 3 e 4 sono stati usati pseudo-participi passati basati su radici regolari di 1° coniugazione e suffissi flessivi di verbi sub-regolari di 2° coniugazione. Negli Esperimenti 5 e 6, l'indagine sulla 1° coniugazione è stata estesa tramite l'impiego di pseudo-forme sub-regolarizzate dell'indicativo presente e futuro.

I risultati di tutti gli esperimenti hanno mostrato un'interferenza reciproca tra *pattern* regolari e sub-regolari, basata su un effetto inibitorio sul riconoscimento delle pseudo-forme sia regolarizzate che sub-regolarizzate. Tale effetto ha coinvolto anche le radici regolari di 1° coniugazione, contro l'ipotesi avanzata da Say e Clahsen (2001), secondo la quale la 1° coniugazione costituirebbe la classe regolare di *default*, insensibile ad effetti di somiglianza fonologica.

Nell'Esperimento 7 sono state messe a confronto pseudo-forme flesse regolarizzate e sub-regolarizzate di verbi regolari, irregolari e sub-regolari delle tre coniugazioni dell'italiano, allo scopo di ottenere una misura dell'interferenza reciproca tra questi *pattern*. I risultati hanno mostrato un effetto inibitorio sul riconoscimento delle pseudo-forme di tutte le condizioni, più forte sulle pseudo- forme regolarizzate che su quelle sub-regolarizzate. Tali risultati sembrerebbero indicare che l'attrattività dei *pattern* sia legata alla numerosità e alla frequenza dei verbi appartenenti ad una stessa famiglia flessiva.

L'Esperimento 8 è stato basato su un compito di produzione di forme flesse reali di verbi di 2° e 3° coniugazione. I risultati, che hanno confermato l'effetto di somiglianza morfo-fonologica riscontrato nei compiti

di riconoscimento, indicano che la dominanza dei *pattern* regolari o sub-regolari in ciascuna delle classi flessive sia influenzata dalla distribuzione di verbi regolari e sub-regolari all'interno della stessa classe.

Infine, l'Esperimento 9, basato su un compito di produzione di forme flesse di verbi nuovi, è stato concepito come una replica di un esperimento simile riportato da Say e Clahsen (2001). In questo esperimento sono stati usati pseudo-verbi simili a verbi reali di tutte le classi flessive dell'italiano, e pseudo-forme verbali non simili a forme reali. L'obiettivo era quello di testare la generalizzabilità dei *pattern* regolari e sub-regolari dell'italiano. E' stato osservato che la generalizzabilità dei *pattern* era fortemente influenzata dalla somiglianza tra verbi reali e verbi nuovi. Inoltre, il *pattern* regolare di 1° coniugazione non è stato sempre usato come modello di *default* sugli pseudo-verbi non simili a verbi reali, contrariamente a quanto osservato da Say e Clahsen.

Nell'insieme, questi dati non sembrano giustificare la necessità di fare riferimento ad un modello simbolico che distingua tra due meccanismi di accesso lessicale. Piuttosto, essi sembrano interpretabili in base all'ipotesi sostenuta da Burzio (1998), il quale sottolinea che la probabilità di attivazione di un *pattern* flessivo

sarebbe legata non alla regolarità o irregolarità del modello, ma alla sua coerenza, che a sua volta dipenderebbe dalla numerosità e frequenza dei verbi appartenenti alla stessa famiglia flessiva, oltre che dal numero e alla robustezza delle relazioni morfologiche tra forme flesse.

Foreword

The aim of this experimental study is to investigate the representation and processing of regular, sub-regular and irregular verbal forms of Italian. In psycholinguistics, the debate on the processing of regular and irregular verbs is based on the contrast between Dual Mechanism models (Pinker and Prince, 1988; Clahsen, 1999; Caramazza, Laudanna and Romani, 1988), which claim that regular forms are processed through the application of inflectional rules, while irregular forms are retrieved as whole words from the associative memory, and Connectionist models (McClelland and Patterson, 2002; Joanisse and Seidenberg, 1999; Rumelhart and McClelland, 1986), which claim that a single associative mechanism accounts for both regular and irregular form processing. Despite Dual Mechanism models clearly support distinct mechanisms for the representation of regular and irregular verbs, several studies point out that this dichotomy is challenged by the existence of families of "sub-regular" verbs, which share morpho-phonological features and follow the same inflectional patterns.

The debate on sub-regular patterns evolved especially with respect to languages like Italian, based on the organization into inflectional classes, each characterized by a specific regular paradigm, and on a varying aggregation of sub-regular families.

The coexistence of multiple regular patterns and sub-regular families seems to be consistent with the Optimality Theory (Prince and Smolensky, 1993; Benua, 1997, Bernhardt and Stemberger, 1998; Smolensky, 1999), which departs from the traditional concept of inflectional rule and invokes the use of phonological constraints, based on phonological analogies between surface forms of words and on different degrees of relevance and "violability".

In the present study we conducted a set of experiments on the recognition and production of inflected forms of regular, irregular and sub-regular real verbs belonging to the three inflectional classes of Italian, and on pseudo-verbal form processing. The lexical decision experiments (1-7) were designed to test the possibility: 1) that the activation of a regular pattern is inhibited by the competitive activation of a sub-regular pattern appropriate for one or more morpho-phonologically similar verb, and 2) that the activation of a sub-regular pattern is inhibited by the competitive activation of a

regular paradigm. This hypothesis was tested through the use of pseudo-inflected forms based on sub-regular roots morpho-phonologically similar to regular verbs, combined with a regular inflectional suffix, and regular roots combined with the inflectional suffix of a morpho-phonologically similar, sub-regular verb. Each list of pseudo-words was used in lexical decision tasks with priming (in which the pseudo-forms were preceded by the infinite form of the verb modified) and in simple lexical decision tasks, in order to test putative inhibitory effects both in contexts that pre-activate the verbal root, and through the presentation of pseudo-words in isolation.

In Experiments 1 and 2 we used pseudo-past participles of the 3rd conjugation verbs. In Experiments 3 and 4, pseudo-past participles based on regular roots of the 1st conjugation and inflectional suffixes of sub-regular 2nd conjugation verbs were used. In Experiments 5 and 6, the investigation on the 1st conjugation was extended through the use of sub-regularized pseudo-forms of the present and future indicative.

The results of all experiments show a mutual interference between regular and sub-regular patterns, based on an inhibitory effect on the recognition of both sub-regularized and regularized pseudo-forms. This

effect involved also the 1st conjugation regular roots, against the hypothesis advanced by Say and Clahsen (2001), according to which the 1st conjugation would be the default class, insensitive to effects of phonological similarity.

In Experiment 7 regularized and sub-regularized pseudo-forms of regular, irregular and sub-regular verbs of the three conjugations of Italian were compared, in order to obtain a measure of the mutual interference between their patterns. The results showed an inhibitory effect on the recognition of pseudo-forms of all conditions, stronger on regularized than on sub-regularized pseudo-forms. These results seem to indicate that the attractiveness of each pattern is related to the number and frequency of the verbs belonging to the same inflectional family.

Experiment 8 was based on a task of production of real inflected forms of verbs of the 2nd and the 3rd conjugation. The results, that confirmed the morpho-phonological similarity effect found in the recognition experiments, suggested that the dominance of regular or sub-regular patterns within each inflectional class is influenced by the distribution of regular and sub-regular verbs within the same class.

Finally, Experiment 9, based on a production task of inflected forms of novel verbs, was conceived as a replication of a similar experiment reported by Say and Clahsen (2001). In this experiment we used pseudo-verbs similar to real verbs of all the verbal inflectional classes of Italian, as well as pseudo-verbal forms not similar to real ones. The goal was to test the generalizability of regular and sub-regular patterns of Italian. We observed that the generalizability of each pattern was strongly influenced by the similarity between pseudo-verbs and real verbs. Furthermore, the regular pattern of the 1st conjugation was not always used as a default on pseudo-verbs not similar to real verbs, contrary to what Say and Clahsen observed.

In sum, the data do not justify the need to refer to a model that distinguishes between two mechanisms of lexical access. Rather, they are interpretable on the basis of the hypothesis made by Burzio (1998), who points out that the probability of activation of a pattern is not linked to the regularity or irregularity of the model, but to its consistency, which, in turns, depends on the number and frequency of inflected verbs belonging to the same family, as well as the number and robustness of the morphological relationships between inflected forms.

Chapter 1 .
Issues on morphological processing: Rule Based vs. Parallel Distributed models

1.1 Regular and irregular verbs

One of the aims of psycholinguistic studies is to investigate the use of implicit grammatical rules to produce and comprehend language. One of the main psycholinguistic issues concerns the processing of morphologically regular and irregular verbal forms. More specifically, the debate focuses on which kind of information is subject to storage, and what is the role played by lexical rules in combining units of stored knowledge. On morphological grounds, a word is considered regular if it follows the traditional paradigm of its inflectional class. A regular word is transparent with respect to its internal structure: it can be parsed into *stem+affix*. On the contrary, irregular forms do not follow the inflectional rule, assuming different affixes, stem variations or suppletive forms of the stem. From a diachronic perspective, irregularity is often the result of a regular sound change which occurs in certain phonetic

environments and affects parts of the inflectional paradigm.

Many psycholinguistic studies addressed the problem of the recognition of morphologically complex words, with particular attention to the conditions which determine the processing by decomposition into morphemes, or by retrieval of the entire form. Experimental studies show that the probability of morphological decomposition of the word depends on factors like the length of the word, the phonological and semantic transparency of the inflected form with respect to its base form, and the number of words containing the same morphemes. These effects were interpreted by models that include two parallel routes of access to the lexicon: a faster route, based on whole forms, and a slower route, based on decomposition into morphemes. Among these, the AAM (Augmented Addressed Morphology) (Caramazza, Laudanna and Romani, 1988; Chialant and Caramazza, 1995), hypothesizes that morphological decomposition is more likely to occur for infrequent words or neologisms, that are not represented in the mental lexicon. The Race Model (Schreuder and Baayen, 1995), states that both pathways are activated in parallel for all the words, and that the success of a route over the

other is related to the frequency of the word processed (a more frequent word will have a faster whole form access, while a less frequent form will be more easily processed through the decompositional route). In light of these claims, differences in the processing of morphologically regular and irregular verbs are related to the phonological transparency that allows to parse a word through its morphemes.

1.2 Sub-regular verbs

Chomsky and Halle (1968) noticed that it is possible to identify groups of irregular verbs which are morpho-phonologically similar and share the same inflectional pattern, as it is the case of verbs like *blow-blew*, *grow-grew*, *know-knew*. These irregular patterns can be considered as an intermediate case between regulars and irregulars: indeed, they are characterised by an internal consistency that makes them partially predictable on the basis of their morpho-phonological similarity. In their Generative Phonology theory, Chomsky and Halle argued that the existence of this kind of irregularities suggests a similar processing mechanism for regular and irregular verbs, providing that an irregular form like *feel-felt* is processed through the application of a rule that modifies the stem.

According to lexicalist theories (Jackendoff, 1975; Aronoff, 1976; Lieber, 1980), such irregular paradigms cannot be considered as arbitrary phenomena, although they are not fully systematic and productive. The regularity of inflected words is accounted for by the notion of "lexical redundancy rules", which defines morpho-phonological patterns that can be generalized by analogy.

Sub-regular inflectional patterns were accounted for in the Minimalist Morphology theory (Wunderlich and Fabri, 1995), based on the distinction between lexically restricted inflection and affixation. In the MM theory, irregular inflection is considered lexically restricted because it is encoded in the lexical entry as additive information. Regular inflection, on the contrary, is a combinatorial process which combines stems and affixes, considered as different lexical entries. Sub-regularities are interpreted on the basis of lexical templates, linking stem fragments to affixes through sub-nodes.

The question about regularity and irregularity was explored from a new perspective by the so-called "Minimal generalization Model", introduced by Pinker and Prince (1993) and subsequently developed by Albright and Hayes (2002). This theory assumes

morphological processes to be based on phonological rules identified by the speakers in the phonological space of a specific language. A rule of this kind describes a change through the phonological features of a verbal paradigm, and can be generalized on the basis of the morphological features shared by forms following the same inflectional pattern. The set of features characterising a specific rule is called "Island of Reliability": the more similar a root is to the prototype described by a rule, the higher is the probability for the root to follow that rule.

1.3 The debate between Dual Mechanism and Single Mechanism accounts

In the last decades, the research on language processing has seen the opposition between "Dual Mechanism" and "Single Mechanism" models.

Dual-route accounts (Pinker and Prince, 1988; Clahsen, 1999; Caramazza, Laudanna and Romani, 1988) are based on the distinction between mental lexicon and mental grammar. Mental lexicon is the representational level of speaker's lexical knowledge, containing information about all phonological, morphological, syntactic and semantic properties of words. According to Ullman (2001b, 2004), the mental lexicon contains all

non-compositional simple words whose forms and meanings cannot be derived from each other.

Mental grammar is a set of recursive, combinatorial rules that allow the speaker to create inflected, derived or new words. This opposition implies a separation between the associative memory system involved in storage and retrieving of irregular forms, and the combinatorial procedures employed for processing regular forms. According to these models, irregular words are recognised as non-decomposable units of language, and so registered in memory as whole forms. In contrast, regular words are processed through their morphemes, each of whom is retrieved from memory.

Single-mechanism accounts (Bird, Lambon-Ralph, Seidenberg, McClelland, and Patterson, 2003; Joanisse and Seidenberg, 1999; McClelland and Patterson, 2002; Rumelhart and McClelland, 1986) hypothesize that regular and irregular forms are represented as units of a connectionist system, linked to each other through orthographic, phonological and semantic connections.

The debate between dual-route and connectionist models starts from the dispute between "symbolic" and "sub-symbolic" approaches to knowledge representation, which were developed in cognitive sciences: the first is oriented to the analysis of

phenomena through the implementation of rules and the manipulation of symbols; the second aims at describing phenomena through the construction of neural networks.

Detractors of connectionist interpretation often claim that it tends to oversimplify the process of language acquisition: according to the symbolic approach, human brain is provided with a specific grammar-module containing universal grammatical rules, that children adapt to a specific grammar during the language acquisition. The existence of innate rules would be proved by the fact that each inflectional system (verbal, nominal, etc.) is marked by the presence of a strong productive pattern, which can be generalized by default. Conversely, connectionist theorists argue that the symbolic interpretation is not sufficient to explain the behavior of minor inflectional patterns shared by groups of verbs, already identified by Chomsky and Halle (1968). What makes these patterns different from idiosyncratic ones is their being at least partially predictable, as it is suggested by the fact that a neural network, trained to produce regular and irregular verbal forms, is able to generalize inflectional patterns on the basis of phonological similarity between new and learned verbs.

1.4 The Interactive Activation model

Connectionist models are usually applied to study the development of cognitive skills, through the construction of computational algorithms. Their network structure was inspired by the structure of neurons and synapses in the brain. Rejecting the assumption that human brain acquires information on the basis of a pre-existing innate knowledge, these models introduced the idea of a distributed representation, emerging from a self-organizing system of interconnected simple units. Assuming that regular and irregular processes can be expressed by a mechanism which does not involve the explicit representation of rules, Rumelhart and McClelland (1986) attempted to reproduce the process of acquisition of the past tense. They implemented a pattern associator for the production of past-tense, based on a two layered feed-forward network. Each unit of the network had a numerical level of activation, and was connected to the other units through excitatory or inhibitory connections of different weights.

An input node might represent, for example, a vowel or a consonant in a specific position within the word in input; output units represented forms of the past tense.

Phonological, semantic and orthographic relations emerged during the training sessions through variations of the strength of connections: after each training epoch, a back-propagation algorithm analyzed the accuracy of the mapping from input to output, matching the given response with the expected response, and updated the weights of connections in order to minimize the error.

Phonological representations of words were based on the *Wickelfeature* format: each word was composed of several nodes representing trigrams of phonemes, called *Wickelphones* (for example, the verb *came*, /kAm/ was represented as #Ka, kAm, aM#); words with wickelphones in commons shared part of their nodes of representation. Given this representational system, the pattern associator was hardly able to predict the relationships between irregular past participles as *went* or *thought* and their base forms, respectively *go* and *think*.

The network was trained to associate paired inputs of a verbal stems and their correspondent past tense forms, then it was tested at producing the past tense of new verbs, given their stems. The training set was based on a large number of regular and irregular verbs of English. During the training phase, the model had a tendency to

over-regularize some irregular roots. At the end of training, the pattern associator had achieved a fair degree of generalization, even failing to catch some sub-regular groups within irregular roots. Regular verbs were responded to faster than irregular verbs, due both to the word frequency an the neighbourhood relationships between base and inflected forms.
Rumelhart and McClelland argued that their network could imitate in a satisfactory way the learning of the past-tense by children.

1.5 The Words and Rules theory

The Rumelhart and McClelland's pattern associator was widely criticised by Pinker and Prince (1988), who maintained that it was not able to account for morphological and phonological regularities, that it learned rules not found in human language, and that it failed to show the same stages of development of language showed by children. Pinker and Prince drew on the concept of lexical redundancy rules introduced by lexicalist theories, stating that they can not be considered as rules at all, but as phonological constraints emerging from memory, which allow the speaker to learn more easily items sharing phonological properties. The "Words and Rules" theory (Pinker and

Prince, 1988; Pinker, 1999) established that the distinction between regular and irregular morphology is directly related to the distinction between mental lexicon and mental grammar: irregular forms are stored and retrieved as single lexical entries from the mental lexicon, incorporating specific grammatical features as "past tense", while regular forms are processed through a concatenative rule which attaches stems and affixes. The concatenative rule is conceived not as a specific rule for the past tense, but as a general procedure that merges word constituents (Pinker and Ullman, 2002).

In Words and Rules perspective, the retrieving mechanism of irregular forms is similar to the associative system hypothesized by the Rumelhart and McClelland's model. However, lexical entries in the mental lexicon vehicle information about phonological, morphological, semantic and syntactic features that are not explicitly represented in the pattern associator.

Given these assumptions, one would expect that irregular verbs would be processed in shorter times than regular verbs, being the direct access to lexicon faster than the application of the rule. Pinker and Prince (1994) and Pinker (1999), on the contrary, maintained that regulars are processed faster than irregulars, on the basis of a "blocking system": the application of the

rule is blocked by the activation of a stored word form, otherwise the rule is applied by default. Blocking the rule involves additional processing costs, and the speed of activation of an irregular form is directly proportional to its frequency and to the number and frequency of its phonological neighbours. Regular forms are generally insensitive to frequency effects, although it is possible that a highly frequent regular form is memorized outright and then benefits from both whole word and rule- based processing.

1.6 The Declarative/Procedural model

Ullman (1997, 2001) proposed a further development of the Words and Rules theory, based on neurological data. According to the Declarative/Procedural hypothesis, the separation between regular and irregular morphological processes lies in different neuro-cognitive correlates: the declarative memory, which stores arbitrary events and relationships, could be the neurological site of the mental lexicon; the procedural memory, which underlies the learning of cognitive and motor skills and implicit knowledge, could control the manipulation of symbols through grammatical rules. Declarative memory is subserved by regions of the medial temporal lobe and temporal and

temporoparietal neocortical regions, while procedural memory involves the frontal cortex, including Broca's area, the basal ganglia, parietal cortex and the dentate nucleus of the cerebellum.

The Declarative/Procedural model shares several predictions with Dual Route models: it confirms the hypothesis of a double dissociation between regulars and irregulars; it admits the possibility of a storage of highly frequent regular forms; it hypothesizes a competitive activation of declarative and procedural memory systems, solved by the blocking mechanism; it states that irregular forms are stored in an associative memory, also similarly to what hypothesized by Single Mechanism models; finally, it supposes that the processing of irregular forms is influenced by effects of frequency and phonological similarity. What makes this model different is the fact that the two memory systems responsible of the double dissociation are not language-specific systems: indeed, although declarative memory contains lexical knowledge, and procedural memory controls the use of morphological rules, it is not excluded that other neurological circuits are involved in the language faculty. Moreover, declarative memory subserves the learning of irregular forms, non-compositional lexical items, and facts or

events at the same time. Similarly, procedural memory underlies the development of morphological rules as well as other grammatical rules or cognitive and motor skills.

1.7 Review of the literature supporting the Dual Mechanism account

An important amount of data in favor of the Dual Mechanism theory was collected in research on native speakers of English. It is known that the English verbal system is less complex as compared to languages like Italian: it is based on a single inflectional class (the regular pattern for past tense consists of the suffix *-ed* attached to the stem), and includes a little number of sub-regular phenomena (such as *keep/kept*, *sleep/slept*, *sweep/swept*). This often led to criticisms about the weakness of the assumptions made by symbolic theory. Research on regular and irregular processing is generally based on recognition tasks, like lexical decision, or production tasks, as sentence completion. Here we will report data from studies on patients with speech disorders, on adults, on language acquisition by children, and from studies based on tecniques for the detection of event-related potentials (ERP) or neuroimaging (PET, MEG, fMRI).

1.8 Findings from patients with speech disorders

An important contribution to the debate on Double vs. Single Mechanism theories comes from studies on patients suffering from a variety of diseases, such as brain lesions (e.g., aphasia), neurodegenerative diseases (e.g., Alzheimer's Disease, Parkinson's Disease), and developmental disorders (e.g., Specific Language Impairment, Williams Syndrome). The Dual Mechanism approach, and in particular the Declarative Procedural model, maintains that the existence of a dissociation between regular and irregular processes would be proven by the fact that different areas of the brain are involved in impairments affecting selectively the processing of regular or irregular forms. On the basis of this assumption, studies on speech disorders are generally focused on specific cortical areas which were demonstrated to be responsible for the language processing. Among these, Broca's area, located in the frontal lobe of the cerebral cortex, involved in the production of language; Wernicke's area, located in the posterior-superior temporal lobe, controlling oral language comprehension; arcuate fasciculus, a bundle of nerves linking Broca's area to Wernicke's area.

Specific lesions to these brain components were demonstrated to be responsible of different impairments: Broca's aphasia determines a grammar deficit, resulting in difficulties in the articulation of sentences, in the use of connectives, and in the production of inflected forms; Wernicke's aphasia is associated to an impairment in understanding and repeating spoken language, and is characterized by a fluent and grammatically correct (but meaningless) speech; conduction aphasia, related to lesions to the arcuate fasciculus, is considered a degeneration of Wernicke's aphasia, being based on a serious deficit in the repetition of auditory stimuli.

In a study by Marslen-Wilson and Tyler (1997), the patients DE and JG, with injuries on the entire frontal left hemisphere, including Broca's area, and the patient TS, suffering from a severe semantic dementia due to damage to the temporal lobe, were tested in a cross-modal priming experiment. The priming effect is an increase (or decrease) of the speed or accuracy in the response to a stimulus, due to the prior exposure to a stimulus that can be identical or related to the target. Many results showed that different types of correlation affect the recognition of target in different ways: the identity condition or a morphological relationship

determine a facilitatory effect (Stanners et al., 1979, Fowler et al., 1985; Kempley and Morton, 1982); a similar effect is observed in the condition of semantic relation, while pairs of homographic roots with different meanings provoke an inhibitory effect (Laudanna, Badecker and Caramazza, 1989).

Marslen-Wilson et al. employed a priming task based on the visual lexical decision paradigm, a task in which subjects have to distinguish between real words and non-words. Studies based on lexical decision showed that the speed of recognition of a word is influenced by its frequency (Balota 1994). According to Dual Mechanism predictions, this effect generally involves irregular forms, but in some cases it emerges also on regular forms (Baayen et al. 1997a, 1997b; 2003; Tabak et al., 2010). Patients with damages to the frontal left hemisphere showed a strong priming effect on irregular past tense forms and on pairs of semantically related words; TS showed opposite results, having a normal performance on regular verbs, no priming effect on irregulars and no semantic or phonological priming effect. The association between semantic processes and irregular forms was confirmed by the pattern of results of ES, suffering from a progressive and severe semantic impairment. In the cross-modal priming

experiment, he showed a significant priming effect on regular forms but not on irregular forms and on semantic related pairs.

Similar results were collected by Tyler, DeMornay-Davies, Anokhina, Longworth, Randall and Marslen-Wilson (2002), who conducted a priming experiment on five patients with damages in the inferior frontal region of the left hemisphere, compared to four subjects with temporal lobe injuries. Being damages to the frontal left hemisphere usually associated to difficulties in repeating whole sentences rather than single words, the patients were tested on a repetition priming task, in which they had to repeat sentences, words and non-real words. They showed a greater ability with real words than non-words and sentences, and a similar result was found on two additional tasks of reading aloud words and non-words. Furthermore, the patients completed a sentence-picture interference task, in which they had to listen a sentence containing pseudo-verbs and associate it to a picture. All patients made many errors based on the inversion between subject and object, but gave more accurate responses in a similar task based on words. In general, all results obtained from these patients show a deterioration of

syntactic competence associated to intact semantic skills.

On the contrary, patients with temporal lobe damages showed severe semantic deficits, but almost intact syntactic abilities, as observed in the sentence-picture interference task. These data seem to confirm the hypothesis that the double dissociation between regular and irregular verbs is associated to a more general dissociation between semantic and syntactic skills, in agreement with the Dual Mechanism theory.

Ullman, Corkin, Coppola, Hickok, Growdon, Koroshetz and Pinker (1997) conducted an experiment of production of past tense forms on a group of patients with various neurological disorders (Alzheimer's disease, Parkinson's disease, Huntington's disease or aphasia involving both the anterior and posterior regions of the brain). Patients suffering from Alzheimer's disease and those with damages to the parietal cortex showed an impairment on the production of irregular forms, while those with Parkinson's and Huntington disease or damages to the anterior region revealed a deficit with regular verbs. More specifically, patients with Huntington's disease produced double-suffixed regular inflected forms, as **walkeded* or **daggeded*, giving correct answers on

irregular stimuli. The authors interpreted these data within the Declarative Procedural Model, stating that the deficits on regular verbs are due to lesions in the fronto-striatal region, which underlies the procedural memory, while deficits on irregular forms are related to damages in the temporo-parietal region, in which the declarative memory is located.

A different pattern of results was obtained by Longworth, Keenan, Barker, Marslen-Wilson and Tyler (2005), who observed no association between lesions in the fronto-striatal region and deficits on regular verbs, in experimental tasks based on the production of inflected forms of regular and irregular verbs in sentences, and on lexical decision with auditory priming.

The validity of the results reported by Ullman et al. (1997) was questioned by Tyler et al., (2002a), on the basis of the fact that the neuropathology of some patients was not established by means of neuroanatomical evidence, but by the observation of their behavioural deficits.

The results by Ullman et al. (1997) were replicated by Joanisse and Seidenberg (1999), who tried to demonstrate that the inconsistency of irregular inflectional patterns makes them predictable on the

basis of semantic rather than phonological properties. They implemented a connectionist model for the production of past participles, provided with a specific module for the storage of semantic properties of verbs in input. Then they tested the model by simulating damages to phonological or semantic units, obtaining a pattern of results similar to that of Ullman et al. (1997). According to Joanisse and Seidenberg, these data seem to demonstrate that a single associative system can account for the double dissociation in the processing of regular and irregular verbs, without invoking the existence of two different processing mechanisms. Moreover, they refused the assumption, made on symbolic grounds, that impairments in the processing of irregular forms are due to deficits in phonological processes. Joanisse and Seidenberg argued that the deficits displayed by Ullman's Alzheimer patients in the processing of irregular verbs can be interpreted as being related to injuries in semantic skills, which are related to Alzheimer disease or to other damages to the posterior brain regions. A similar pattern of results was also obtained by Patterson, Lambon Ralph, McClelland and Hedges (2001), who examined patients with semantic dementia, and by Marslen-Wilson and Tyler (1997, 1998), who showed that patients with a deficit on

irregular forms obtained no effect of semantic priming. However, impairments on irregular forms and semantic deficit seem to be not necessarily associated, as observed by Tyler, Stamatakis, Jones, Bright, Acres and Marslen-Wilson (2004), who found that patients affected by profound semantic deficits were not impaired in the processing of irregular past tense.

Miozzo (2003) examined a patient, AW, suffering from anomic aphasia, an acquired language disorder that causes an inability to recall words or names. Patients with this disorder usually do not show semantic deficits as they are often able to describe the meaning of words that they fail to recover, while the phonological recovery of words is compromised. According to the symbolic approach, anomic patients should show impairments in lexical retrieval of both regular and irregular inflected forms. However, in tasks based on the inflection of a root, difficulties should arise only with irregular roots, given that these words are represented as whole forms in mental lexicon. On the contrary, the inflection of regular roots should be unimpaired, since regular forms are obtained through the combination between the regular suffix and the root. The results obtained by Miozzo seem to confirm this hypothesis: in a picture-naming task, in which the

patient had to find the word that described a figure, AW tried to provide the right word by explaining its meaning, or by using phonologically similar words, which were then discarded. Furthermore, in an experiment of forced-choice recognition, the patient showed to have difficult to access the lexical phonology of the words that she omitted.

Finally, AW successfully performed a word repetition task, and this last result excludes the possibility of an impairment in the phonological articulation of words.

AW was also administered with a task of sentence completion, in which she had to complete sentences with inflected forms suggested by the experimenter. She performed the task correctly with regular verbs, and produced a high number of errors with irregular forms.

In producing new inflected forms of pseudo-verbs, which could be similar or different from real irregular roots, AW showed a strong tendency to apply the suffix *-ed* to the pseudo-roots similar to real verbs, leaving the others uninflected.

Finally, in a task of production of regular and irregular plurals, the patient showed the same tendency to inflect correctly regular nouns, giving a lot of wrong answers on irregular ones.

The results reported by Miozzo show that anomic aphasia derives from a deterioration in the phonological retrieval, which leaves intact semantic and syntactic skills, impairing selectively the processing of irregular verbs.

Miozzo and Gordon (2005) reported new data on the case of patient AW, along with those from another patient, VP, suffering from a severe declarative memory deficit, who was impaired in the retrieval of the meaning of words, and displayed a fluent but meaningless speech. The two patients were tested in semantic and episodic memory tests. AW performed almost flawlessly on both tasks, while WP showed a deficit in semantic as well as episodic memory. Furthermore, in tasks of language production and assessment of sentence accuracy, VP obtained a good performance on the production of regular and irregular inflected forms, while AW confirmed the deficit found in previous data on the production of irregular words. As it was argued by the authors, these results seem consistent with the Words and Rules theory, since they confirm a dissociation both between regular and irregular lexical processes and between mental lexicon and semantic system. Moreover, Miozzo and Gordon underlined that none of the two cases show a

correlation between damages in semantic system and production of irregular forms, contrarily to what predicted by Joanisse and Seidenberg (1999).

Finally, these data show an incompatibility with the Declarative/Procedural model: AW had serious difficulties in the production of irregular words but could easily perform tasks that involved declarative memory, while VP had problems in semantic and episodic memory tasks, but could easily produce both regular and irregular inflected forms.

Miozzo, Fischer-Baum and Postman (2010) reported data from JP, a patient suffering from injuries involving the inferior frontal and pre-central gyrus, as a consequence of a stroke. The patient showed a severely impaired spontaneous speech, due to agrammatism, characterized by a scarce production of words, a predominance of nouns and a frequent omission of inflections and function words. To investigate his ability to access noun stems, JP was administered with an object picture naming task, and a word elicitation task, in which he had to produce inflected nouns and pseudo-nouns to complete auditorily presented sentences.

In both tasks, the access to stems resulted unimpaired, since most of errors were based on incorrect inflection of regular nouns. JP confused singular and plural forms,

and gave approximately the same number of singular and plural correct responses. The same tasks were then conducted in order to test the inflection and the access to lexical and semantic knowledge about verbs. The results showed an impaired lexical access for verbal stems, confirmed by a difficulty on inflection of irregular forms. Furthermore, responses on regular verbs were more accurate than that on irregular ones, despite the performance of the patient was significantly worse than the one of control groups on both types of verbs. Pseudo-verbs resulted to be impaired at the same degree of pseudo-nouns, allowing the authors to exclude that the differences between verbs and nouns could be attributed to the great number of inflected forms of verbal paradigms. According to the authors, while the results on nouns undoubtedly indicate the autonomy of inflection from phonological and semantic processes, the more complex data on verb processing seem to demonstrate that lexical impairments could affect inflection production, probably because the choice of inflection in English depends partly on stem information stored in the lexicon.

Selective impairments were also detected in studies on patients with developmental disorders. Bromberg, Ullman, Coppola, Marcus, Kelly, and Levine (1994) for

example, tested adults with Williams Syndrome, a genetic neurodevelopmental disorder associated with severe mental disability that leaves syntactic abilities intact, but impairs lexical retrieval (Ullman and Gopnik, 1999; Bellugi, Wang and Jernigan, 1994). Patients were found to be less impaired at producing regular past tense forms than irregular past tense forms, and produced an high number of over-regularisation errors on irregular forms. Similar results were reported by Clahsen and Almazan (1998; 2001).

More recently, Walenski, Weickert, Maloof and Ullman (2010) reported data from patients with schizophrenia, a psychiatric disease often associated with grammatical as well as lexical impairments, that are assumed to depend from a "thought disorder", namely, the difficulty in combining thoughts into sentences and sentences into coherent discourse (Aloia et al., 1998; Andreasen, 1986; Goldberg et al., 1998; Sanders et al., 1995; Spitzer, 1997). In the study by Walenski and colleagues, patients were asked to produce past tense forms of English regular, irregular and novel verbs. The data showed that patients were less accurate at producing regular and novel past-tense forms than irregular ones, thus demonstrating a dissociation between impaired grammatical processing and spared

lexical access. Furthermore, the higher number of production of unmarked regular vs. irregular forms is consistent with the declarative-procedural model, confirming previous data on grammatical/procedural impairments (Ullman et al., 1997).
The literature on patients with speech disorders shows quite unambiguously that the processing of regular and irregular forms can be selectively affected by specific neurological deficits. Although many studies point to an association between semantic deficits and impairments in processing irregular forms, it remains an open issue whether the relevant dissociation is the one between declarative and procedural memory or the other between semantic and phonological system.

1.9 Experimental data on adult speakers

A contribution to the research on the processing of regular and irregular verbs comes from the studies conducted on German by Clahsen and colleagues, based on the assumptions of the Dual Mechanism model, which, in their view, can be situated in the Minimalist Morphology framework.
Clahsen, Eisenbeiss and Sonnenstuhl (1997) applied the lexical decision paradigm to a study on the formation of the German past participle. German past participle may

have two different endings: the *–n* suffix for the "strong" verbs (irregular verbs, predominantly of high frequency) and the " weak" *–t* suffix which can be considered the default, as it usually marks low frequency verbs and new verbs.

By comparing groups of strong and weak verbs of high and low frequency, the authors observed a frequency effect only on the strong class. Similar results were obtained in a lexical decision tasks on regularly and irregularly inflected forms of nouns. They interpreted these results as a proof that irregular forms are retrieved as entire forms from the mental lexicon, while regular forms are processed through a concatenative mechanism which is insensitive to word frequency.

In an elicited production experiment, Clahsen (1997) collected data on the use of the *–t* suffix as the default pattern. Subjects were presented with novel weak and strong verbs in the infinitive and in the first person simple past form, and their task was to produce the past participle of the novel verbs in sentence contexts. The data showed a strong tendency to generalize the weak suffix, and a generalization of the strong suffix restricted to novel verbs similar to strong existing ones. Similar results were obtained by Marcus, Brinkmann, Clahsen, Wiese and Pinker (1995), in an experiment on

English nouns. Subjects were presented with novel nouns which could rhyme or not with existing ones, and their task was to complete sentences by producing the corresponding pseudo-inflected plural forms. The subjects used more often irregular endings on pseudo-nouns similar to existing irregular ones, while the *–s* suffix was used mainly on nouns which did not rhyme with any existing noun. Such findings on regular and irregular nouns were confirmed by Berent, Pinker and Shimron (1999) on Hebrew nouns.

A different behaviour of strong and weak suffixes was observed by Clahsen (1999) in a sentence-matching experiment, in which subjects had to decide as quickly and accurately as possible whether two stimuli projected on a screen were the same or not. Reaction times during this task were demonstrated to be sensitive to grammatical well-formedness, because well-formed forms are responded more quickly than ill forms (Chambers and Forster, 1975, Friedman and Forster, 1985). Results showed that reaction times were longer for weak pseudo-verbs incorrectly inflected with the *–n* suffix, as compared to those presented with the correct *–t* suffix. However, strong pseudo-verbs did not show any particular effect. According to the author, these data give further support to the Dual Mechanism

theory, since they demonstrate that the combination of an irregular suffix with a pseudo-root similar to a regular root determines the violation of a grammatical rule, which affects the recognition. Pseudo-roots similar to irregular ones, on the contrary, do not activate the concatenative rule, giving rise to no inhibitory effect.

Schreuder, de Jong, Krott and Baayen (1999) argued against the absence of a frequency effect on regular forms (Clahsen et al. 1997), by presenting data collected in a visual lexical decision task on German inflected verbal forms marked by the regular *t*-suffix. Their results showed that high frequency forms elicited faster RTs and less errors as compared to low frequency forms. The authors interpreted these findings as confirming that both parsing and direct access mechanisms are activate in parallel for the lexical access of inflected words. In this perspective, one can hypothesize that low frequency words have a faster decomposed access, while high frequency words are accessed faster through the retrieval of the entire form. The frequency effect found by Schreuder et al. (1999) was confirmed by Sereno and Jongman (1997) on regular nouns of English.

Instead, Clifton, Cutler, McQueen and Van Ooijen (1999) confirmed the results by Clahsen et al. (1997), reporting data from an experiment in which subjects had to write by dictation phonologically ambiguous words of English. Experimental stimuli were based on couples of homophones which could be either monomorphemic words or inflected verbal forms, both regular or irregular. By keeping controlled the frequency difference in each monomorphemic-inflected pair, the authors observed that only the choice of irregular inflected forms was influenced by their higher or lower frequency with respect to the monomorphemic words, while monomorphemic responses were preferred to regular inflected forms even when the latter had an higher frequency. Such results could be interpreted as showing a processing difference between regular and irregular verbs: if irregular forms are processed as whole words, they should not show differences in processing as compared to monomorphemic words, and this assumption is confirmed by the fact that responses on monomorphemic-irregular inflected pairs were influenced only by the form frequency. On the contrary, the hypothesis of a rule based processing for regular verbs is strengthened in that they suffered from a

disadvantage with respect to monomorphemic homophones, probably due to their higher processing costs. However, Clifton and colleagues, though admitting that their results seem to be in accordance to the hypothesis put forward by Clahsen and colleagues, maintained that Clahsen's interpretation, which is based on a general distinction between two processing routes, is limited to a strictly linguistic perspective, that does not specify if this distinction is limited to a modality specific lexical access or to a modality independent level of representation. Clahsen (1999) replied that Dual Mechanism models are focused on the modality independent central representation of verbs, and that the results of Clifton et al. (1999) confirm the hypothesis of different representational systems.

Laudanna (1999) highlighted some limitations of the work by Clahsen and colleagues:

- they identified the compositional account for the processing of regular forms with a rule-based approach, although there are several studies that support the same compositional processes, without invoking a rules-based system;
- if combinatorial rules are involved in the manipulation of roots and suffixes, the

activation of these components in the input units could be affected by effects such as frequency;

- Clahsen did not take into account sub-regular patterns shared by small groups of irregular verbs, which, as observed by Caramazza et al., (1988) in a lexical decision experiments, often show morphological decomposed representations similar to those of regulars;
- it is necessary to clarify the role played by other factors, such as productivity, that is the property of certain morphemes of a language to be recombined to produce new forms, or frequency, which can be considered at different levels, as both whole word frequency and morphemic frequency. In this perspective, a low frequency word containing a high frequency morpheme is more likely to be processed through a compositional mechanism, while a high frequency word can be represented as a whole form even if it is regularly inflected.

Interesting results on morphological processing were obtained with experiments based on cross-modal priming paradigm. In this paradigm, a visual target stimulus is preceded by an auditory prime. Stanners et

al. (1979) found a strong priming effect on regular inflected forms, and other studies confirmed these results (Kempley and Morton 1982, Napps 1989, Fowler et al. 1985, Marslen-Wilson et al. 1993). Kempley and Morton (1982) found no priming effect on irregular forms, while Fowler et al. (1985) and Forster et al. (1987) observed a full effect. Marslen-Wilson et al. (1993), carried out a cross-modal lexical decision experiment on irregular patterns of past tense in English, distinguishing between "semi-weak" inflectional models, involving the change of the thematic vowel plus the addition of the suffix-t (e.g. *felt-feel*, *burnt-burn*) and inflections based only on the change of thematic vowel (e.g. *sang/sing*, *gave-give*). Couples of regular verbal forms like *jumped/jump* were compared with couples of semi-weak and vowel change forms. While regular verbs obtained a full priming effect, semi-weak verbs did not show any effect, while vowel-change couples showed inhibition, probably due to the existence of two distinct mental representations competing with each other.

Sonnenstuhl, Eisenbeiss and Clahsen (1998) reported two cross-modal repetition priming experiments on verbal past participle and nominal plural in German: subjects listened to an auditory prime (a noun or a verb)

and then they had to make a lexical decision on a visual stimulus. Primes and targets could be the same, or morphologically related, or different. Authors expected to find a strong facilitatory effect on regular *-t* past participles and nouns, both in the identity and similarity condition, being the response facilitated by the separated activation of the root and the suffixes. On irregular *–n* participles and nouns, however, the effect on the second condition was expected to be smaller than that on first, due to the fact that morphological related irregular forms activate different representations.

In both experiments with nouns and verbs, the results showed shorter reaction times in the first condition for both categories but, while regular participles and nouns obtained a morphological priming only slightly lower than identity condition, morphological priming effect was very weak and not significant on irregular participles and nouns.

Smolka, Zwitserlood and Rösler (2007) criticized the design of Sonnenstuhl et al. (1998): firstly, the identity condition was based on inflected forms, differently from other studies on English, where the prime was the root form; according to the authors, it could have been interesting to verify if the root priming effect has the

same magnitude as identity priming. Secondly, an analysis on the experimental stimuli revealed that irregular inflected forms had a much higher frequency than regular ones. Thus, the difference between identity effect and morphological similarity effect were determined by a frequency effect in the identity condition.

One of the points of debate between symbolic and connectionist models is whether processing of regular and irregular forms is influenced by the same effects, such as "neighbourhood size effect", a phenomenon whereby large neighborhoods facilitate lexical access (Andrews, 1989). According to connectionist theories, frequency and neighbourhood effects involve both regular and irregular forms, but the influence of the neighbourhood size on regular words is so strong to overwhelm the contribution of form frequency (Daugherty and Seidenberg, 1992; Seidenberg, 1992). Dual mechanism models, on the contrary, hypothesize that if regular forms are processed through a concatenative rule, then they should be insensitive to frequency or phonological neighbourhood effects.

Ullman (1999) tested the influence of neighbourhood size and frequency on regular and irregular forms, by conducting an acceptability rating task on English

verbs. Each verb, regular or irregular, was presented in the present and past tense forms, inserted in two different sentence contexts. Subjects had to define the degree of "naturalness" of the verbs (if they "sounded good") relative to the sentences. The results showed that only the ratings on irregular verbs were influenced by their frequency and neighbourhood size, confirming what had been predicted by Dual Mechanism models.

Dual Mechanism theories assume a general dichotomy between the representation of regular and irregular complex words, involving different cognitive skills and, according to the Declarative-Procedural model, different cerebral substrates. A more complex framework arises in studies on languages that are different from English or German. Some inflectional systems, like verbal systems of Italian, Portuguese and Spanish, are articulated in arbitrary classes which provide different forms for the same morphosyntactic features. Each of these inflectional classes is characterized by a specific regular paradigm, and by a number of exceptions which follow different inflectional patterns. Some experimental studies were devoted to investigate how the existence of different inflectional classes, and different regular patterns within the same inflectional system, might be framed

within the Dual Mechanism theory. Among these studies, Brovetto and Ullman (2005) carried out two experiments on the production of inflected forms of new verbs of Spanish. In the first experiment, novel verbs of 1st and 2nd conjugation, which could be similar or not to existing regular verbs, were used. The authors observed that only new verbs similar to 2nd conjugation existing ones were sensitive to a neighbourhood effect, while the other pseudo-verbs were inflected accordingly to their conjugation. In the second experiment, in which pseudo-verbs similar to existing regular or irregular verbs of 1st, 2nd and 3rd were used, the results showed a strong tendency to the irregularization of new verbs similar to irregular 2nd and 3rd conjugation ones. These data were interpreted as evidence for the hypothesis that, in an inflectional system based on different inflectional classes, it is possible to identify a full productive class which is likely to be used as the default pattern, regardless of factors such as the phonological similarity.

According to Veríssimo and Clahsen (2009), in an inflectional system based on inflectional classes, (e.g., verbal system of Portuguese), only an unrestrictedly productive class is rule-based: forms of this class are processed through the retrieval of the basic root and

the application of a concatenative rule. Non-productive Inflectional classes (which display cases of allomorphy) are presumably based on a whole-word processing, with multiple stem allomorphs stored in the lexical entries. Hence, morphologically related verbal forms of the default class are expected to determine a stronger priming effect with respect to related pairs of non-default classes, because of the higher consistency between form and meaning in the default category. Veríssimo and Clahsen attempted to demonstrate their hypothesis by conducting a lexical decision experiment based on cross-modal priming. They used pairs of infinitives and 1 person of the present indicative of 1st and 3rd conjugation, transparent with respect to the class membership (e.g. *limito/limitar*, or *adquiro/adquirir*), and an additional category of 1st conjugation pairs containing a phonological vowel alternation (af[o]go (afogo)/af[u]gar (afogar)). The magnitude of the priming effect was measured against to an identity condition (pairs of identical prime and target), and an unrelated condition (pairs of forms of different verbs). Results showed a full priming effect on 1st conjugation pairs and a partial effect on 3rd conjugation and 1st conjugation with vowel change pairs, confirming the starting hypothesis.

The experimental data discussed so far converge in demonstrating that, while word frequency and phonological similarity affect processing and generalizablity of sub-regular patterns, they have no effect on processing and generalization of regular models. However, it could be useful to deepen the investigation on verbal systems based on inflectional classes, or characterized by the presence of morpho-phonologically consistent sub-regular families, in order to verify if the generalizability of regular patterns has to be necessarily ascribed to a rule-based system or depends on the predictability of morpho-phonological alternations.

1.10 Children's acquisition of regular and irregular verbal morphology

Studies on language acquisition in children were often framed within the traditional debate between symbolic and connectionist approaches. Starting from the theory of "Generative Grammar" introduced by Chomsky (1957), a number of studies were conducted in order to explore the possibility that language acquisition by children is based on the adaptation of innate rules to the grammatical rules of a specific language.

Many studies focused on errors made by children in early stages of learning (Marcus et al., 1992; Plunkett and Marchman, 1993) suggested that, in a first stage, children are able to correctly inflect a restricted set of verbs. At a later stage of development, they would go through a period in which the increase of lexical knowledge corresponds to a sudden decrease of accuracy, displayed by the tendency to over-regularize irregular verbs. This developmental trend was defined "U-shaped curve", and was interpreted within the Dual Mechanism framework as evidence that children are able to identify and generalize an abstract grammatical rule. This explanation is opposite to the one provided by connectionist theoricians, (Rumelhart and McClelland, 1986) who stated that such a trend in language acquisition can be simulated by a unique neural network, and can be therefore captured by a single route mechanism.

Bybee and Slobin (1982) found that over-regularization errors are influenced by frequency: children tend to regularize low-frequency irregular verbs, and are more accurate on high frequency irregular verbs. According to Marcus et al. (1992), this finding demonstrates that children learn a general rule, which is used as a default when lexical access to an irregular verb fails.

Clahsen and Rothweiler (1993), Weyerts and Clahsen (1994) and Weyerts (1997) carried out several experiments on the acquisition of German past participle production on a group of nine children, and observed a strong tendency to make over-regularizations with the *-t* suffix on strong verbs and, conversely, a significantly less frequent occurrence of irregularizations deriving from the application of the *-n* suffix on weak verbs. According to these authors, the data seem to clearly indicate a dissociation between regular and irregular verbs, when low type frequency of regular verbs with respect to irregular allomorphs.

Clahsen, Rothweiler, Woest and Marcus (1993; 1996b), Bartke, Marcus and Clahsen (1996) and Bartke (1998), obtained similar results on the production of German plural: in a first experiment, based on the production of plural forms of pseudo-nouns, a strong tendency to generalize the default s-suffix was observed. In a second experiment, based on an acceptability judgement task on plural forms of new nouns, children preferred the irregular suffix only on pseudo-nouns phonologically similar to existing irregular ones, and chose the regular suffix in the other cases.

Once again, the results of both experiments confirm the hypothesis of a direct access to the mental lexicon

for irregular inflections, and the use of combinatorial mechanisms during regular processing. As to the U-curve phenomenon, it was hypothesized that, at an early stage of learning, children are able to produce a limited set of correct forms, and have access to a restricted mental lexicon. As the lexicon changes, regular suffixes achieve independent lexical representations, and children are able to produce correct regular or incorrect irregular inflected forms by using combinatorial procedures of root-suffix attachment (Marcus et al., 1992).

In an experiment based on the production of German verbal regular and irregular inflected forms, Clahsen, Hadler and Weyerts (2004) found that children, compared to adult speakers, made more errors based on over-regularizations of irregular verbs, while they were faster and accurate on the production of forms of high frequency irregular verbs. A reverse frequency effect was observed on regular forms, with high frequency forms produced more slowly than low frequency forms, an effect which was not found on the adult group. The facilitation in accessing high frequency irregular lexical items contrasted with the absence of this effect on the production of regular forms by adults, and is also consistent with DM, which assumes that the

use of inflectional rules is not affected by word frequency. The reverse frequency effect found on children, relative to regular verbs, was interpreted by the authors as the result of the competitive activation of a high frequency lexical entry and the combinatorial system.

We have also an experimental study on the acquisition of past perfective forms of Greek, by children and adults (Stavrakaki and Clahsen, 2008). The Greek verbal system has a regular inflectional pattern for past perfective, based on the attachment of the consonant /s/ to the verbal root. The experiment, conducted on children belonging to different age groups and on an adult control group, was based on a task of production of inflected forms and on an acceptability rating task, involving existing and novel verbs rhyming or not with other existing verbs. Both experimental groups used the regular pattern as a default on new verbs not similar to existing ones; the default model was preferred even on pseudo-verbs which were similar to irregular existing verbs. Children of all age groups showed a tendency to over-regularize according to the regular paradigm; older children achieved better results on the inflection of regular existing verbs, than younger children; finally,

most irregularization errors occurred on new verbs similar to irregular verbs.

Gatherchole, Sebastian and Soto (1999) analyzed the spontaneous speech of Spanish-speaking children aged between nine months and two years and six months, observing that children began to produce over-regularizations from the moment they began to use the regular pattern productively. Johnson (1995), studied the spontaneous speech of 42 children between 2 and 4 years, finding different types of regularization errors: in some cases, children over-generalized only the 1st conjugation pattern; in other cases, they used the regular patterns of the 2nd or 3rd conjugation on irregular verbs; in some cases they failed to select the root of an irregular verb; in all cases tested, irregularization errors were absent.

Similar evidence was reported by Ploenning-Pacheco (1995), who studied the spontaneous language of a child between 2.2 and 2.8 years, analyzing in particular the production of verb forms. The child mainly produced two types of errors on verbs: he applied a regular suffix to an irregular verb, or used the 1st conjugation regular suffix on the 2nd and the 3rd conjugation verbs. The same over-regularization errors were found by Serrat and Aparici (1999).

Clahsen, Aveledo and Roca (2002) analyzed the spontaneous speech of a sample of 15 children, aged between 1.7 and 4.7 years. Again, the majority of errors was based on over-regularizations. The number of over-regularizations increased in older children, and irregular verbs showed a frequency effect, as children committed more errors on low frequency verbs.

Summing up, the experimental literature on language acquisition supporting the DM model is based on results consistent with those observed in studies on adults: the development of language faculty determines the recognition of a regular inflectional pattern, which can be used productively on novel verbs, while the proficiency with irregular verbs is directly related to their frequency.

An important role in the research on language acquisition is played by studies on children with neurological diseases involving language faculty, especially children with SLI (Specific Language impairment), a developmental disorder of language, which affects about 7% of children (Leonard, 1998). This disease was often detected in conjunction with other neurological or social disorders (Menyuk, 1964). Children affected by SLI present various problems related to production and comprehension. Among

these problems, it was frequently detected a deficit on inflectional morphology (Bishop, 1994; Gopnik, 1990a, Leonard, 1998; Oetting and Rice, 1993; Rice, Wexler, and Cleave, 1995). There is a debate on the nature of the disorder: according to some authors, the cause would be attributable to a deficit in the processing of stimuli (Bishop, 1997b; Joanisse and Seidenberg, 1998b; Leonard, 1998, Tallal et al., 1996); according to other authors, the specific disorder is especially attributable to grammar acquisition (Clahsen, 1989; Gopnik, 1990a, Rice and Wexler, 1996b, Van Der Lely, Rosen, and McClelland, 1998). The difficulty in identifying the source of the deficit is mainly due to the nature of the differences observed in groups of children with SLI (Aram, Morris, and Hall, 1993, Bishop, Bright, James, Bishop and Van Der Lely, 2000). Van Der Lely (1998) was identified a specific subgroup of children with SLI, defined "G-SLI", characterized by a primary deficit of the computational grammatical system. Children in this group can hardly acquire and manipulate the basic rules of grammar, such as verb-subject agreement or identification of thematic roles in passive or subordinate sentences, and, unlike other children with SLI, they do not show difficulties in logical reasoning, o in pragmatic and conversational inference.

Clahsen and Almazán (1998) compared four children with Williams syndrome with a group of children with normal language skills, and a group of children with SLI. Children with Williams syndrome had no particular problems with tasks such as interpretation of reversible passive sentences or production of regular past participles, but made many errors on irregular verbs. Children with SLI, on the contrary, had more problems on regulars than on irregulars.

Research on children with SLI showed unimpaired production of irregular words, as opposed to a deficit in the use of regular morphology (Leonard, McGregor, and Allen, 1992; Oetting and Rice, 1993; Oetting and Horohov, 1997; Rice et al ., 1995), or the production of a smaller number of over-regularizations as compared to children with a normal development of language (Leonard, 1989, 1998, Marchman and Weismer, 1994; Marchman, Wulfeck, and Weismer, 1999) or, finally, the presence of a frequency effect on regular verbal forms or nouns not found in healthy children (Horohov and Oetting, 1997; Oetting and Rice, 1993; Ullman and Gopnik, 1999).

A research on Dutch children with SLI (Bartke, 1998; Clahsen, Rothweiler, Woeste, and Marcus, 1992) showed, for example, that they tended to over-

generalize the irregular plural suffix *-n* more often than the regular *-s*, which is commonly used as a default by children with normal development.

Other studies report data on children with SLI showing a normal use of regular and irregular inflectional morphology (Clahsen et al., 1992; Marchman et al., 1999; Horohov and Oetting, 1997; Oetting and Rice, 1993).

Van Der Lely and Ullman (2001) investigated the production of inflected forms of the past tense of real or novel regular and irregular verbs, on a group of 12 children with G-SLI (aged from 9.3 to 12.10), compared with 3 control groups of healthy children belonging to different stages of language development (from 5.5 to 8.9). As to production of inflected forms of existing irregular verbs, the authors observed a similar frequency effect both in the experimental and in the control group. All children were faster and more accurate at producing high frequency irregular forms. On regular verbs, a strong frequency effect was detected only on the experimental group. All groups produced less irregularizations than over-regularizations of new verbs; on irregular verbs, SLI children produced approximately the same number of over-regularizations and irregularizations, while the

control groups produced a majority of over-regularizations. According to the Single Route approach, disorders characteristic of SLI are due to a deficit in the processing of acoustic stimuli (Bishop, 1997, Elman et al., 1996, Joanisse and Seidenberg, 1998b; Leonard, 1998; Tallal et al., 1996). This interpretation may explain the frequency and neighbourhood effects found on SLI children, but is insufficient to explain the differences in the performances of SLI and healthy children. Van der Lely and Ullman (2001) interpreted this pattern of disease in children with SLI as the result of a deficit in the acquisition of regular inflectional patterns, as confirming that the G-SLI represents a specific form of SLI, which affects learning and manipulation of abstract grammatical rules (see also Marshall and Van der Lely, 2008).

However, considered the lack of univocity of the data on SLI children, further investigations are necessary to comprehend the relation between this disease and the processes of lexical access.

1.11 Neuroanatomical evidence

The advancement of research on linguistic processes has seen the important contribution of researches

involving electrophysiological techniques for detecting event-related potentials (ERP), and brain imaging techniques (neuroimaging or neurovisualization), such as MRI (magnetic resonance imaging), CT (Computed Tomography) and PET (Positron Emission Tomography).

The use of these advanced detection techniques allows to visualize changes in brain activity during mental routines (perceptive, cognitive, attentional, emotional, etc.), and to test through non-invasive procedures the assumption that specific brain structures would be appointed to control specific forms of information processing.

Some ERP studies led to the identification of patterns of activation involved in language processing:

- N400 (Kutas and Hillyard, 1980), an increase in the amplitude of endogenous negative component, appearing around 300 ms, peaking around 400 ms, in response to a semantic anomaly;
- ELAN (Early Anterior Negativity, Neville et al., 1991; Hahne and Friederici, 1999), an early negative component, with a latency between 100 and 300 ms, in response to a violation of the syntagmatic structure of sentences;

- LAN (Late Anterior Negativity, Neville et al., 1991, Munte et al., 1993), an early negative component, which takes place between 300 and 500 ms, in response to syntagmatic structure violations or agreement violations;
- P600 (Neville et al., 1991; Hahne and Friederici, 1999; Hahne and Jescheniak, 2001; Hahne and Friederici, 2002), a posterior positive component, which follows the ELAN and the LAN, with a peak around 600 ms .

Some neuroanatomical studies focused on testing if the processing of regular and irregular forms might be ascribed to different neuro-cognitive substrates, as it is maintained by the Declarative-Procedural model, or if a single, connectionist mechanism is sufficient to account for the representation of all morphological complex words. Penke, Weyerts, Gross, Zander, Munte, and Clahsen (1997) used event-related potentials in experiments based on the recognition of regular and irregular verbal forms of German, in which a set of real regular and irregular past participles and of novel regularized or irregularized past participles were used. Among the other results, it is interesting to note that regularized past participles elicited a LAN, with a

latency of 200 ms, which did not appear in response to irregularized participles. A similar result was obtained by Weyerts, Penke, Dohrn, Clahsen and Munte (1997), and Lück, Hahne and Clahsen (2006) on regular and irregular nouns of German. According to the authors, these data confirm the existence of a dissociation between the underlying processes and brain areas involved in the production and recognition of regular and irregular words.

However, as noted by Ullman (1999), differences in pattern of activation elicited by incorrect regular or irregular forms, although indicating a dissociation in morphological processing, confound lexical and grammatical processing, since they are based both on a lexical violation and on the incorrect application of an inflectional rule.

Clahsen, Lück and Hahne (2007) reported the results of an ERP study in which groups of children of different ages (six-to-seven, eight-to nine and eleven-to twelve), were presented with sentences containing incorrect plural forms of German nouns. They compared their results with previous data obtained by Lück, Hahne and Clahsen (2006) on adult speakers, and found a broad distribution in the youngest children group, an anterior maximum on older children, and a focal left distribution

in the adult group on over-regularized *–s* plural forms. Furthermore, younger children did not show any positive component, which was found on the other groups. The authors interpreted this change in topography of responses through ages as an expression of the development of the language processing system in the brain, which gradually acquires sensitivity to grammatical violations based on the application of combinatorial rules.

Rodriguez-Fornells, Clahsen, Lleó, Zaak and Munte (2001) conducted an experiment similar to the one performed by Penke et al. (1997), where incorrect forms of the past participle were embedded in sentences. The study was conducted on the verbal system of Catalan, which can be distinguished from other verbal systems, such as those of English or German, as it consists of three inflectional classes; the first and the third are predominantly regular, the second is characterized by a number of sub-regular patterns. Experimental pseudo-words could be: a) regular roots of the 1st conjugation, combined with the thematic vowel of the 3rd conjugation, followed by the regular suffix *–t* (which was the same for the 1st and 3rd conjugation), b) regular roots of 3rd conjugation, combined with the thematic vowel of the 1st, c) regular roots of 2nd conjugation,

combined with the thematic vowel of the 1st, d) 3rd conjugation irregular roots, inflected according to the pattern of regular roots of the 1st conjugation. The data showed a LAN on pseudo-participles of 2nd and 3rd conjugation regular verbs, which was not found on pseudo-participles of the 1st conjugation. These results would suggest that verbs of the 2nd and 3rd conjugation are all stored in memory as whole forms. Therefore, the insertion of the thematic vowel of the default class constitutes the misapplication of a rule on a form that usually blocks the rule, while the insertion of the 3rd conjugation thematic vowel on a 1st conjugation root would not implicate the violation of any grammatical rule.

On all forms a P600 was found, while, in contrast to data from German verbs, the regularization of irregular forms of the 2nd conjugation did not lead to the activation of a LAN. This lack of effects was interpreted on the basis of the fact that irregular verbal forms of Catalan present a variation in the root in addition to the change in the inflectional suffix. Thus, the application of a regular suffix would determine a form that is too different from the correct one.

Munte, Say, Clahsen, Schiltz and Kutas (1999), recorded ERPs in a task based on the repetition priming

paradigm. Other studies of this type (Bentin and Moscovitch, 1992; Bentin and Peled, 1990; Hamberger and Friedman, 1992; Karayanidis et al., 1991; Nagy and Rugg, 1989; Otten, Rugg and Doyle, 1993; Rugg, 1985; Rugg, 1987, Smith and Halgren, 1987; Young and Rugg, 1992) reported repetition effects on real words, figures and well-formed pseudo-words, but not on orthographically irregular pseudo-words. The repetition effect occurs in two phases: an initial reduction of the N400 component between 200 and 500 ms, followed by a positive component (Late Positive Component, LCP), between 500 and 800 ms. This second component is particularly clear on low-frequency words.

The experiment conducted by Munte et al. was based on a lexical decision task with priming, in which English verbs were used. The experimental target stimuli consisted of base forms of regular and irregular verbs, preceded by the past participles of the same verbs. According to the Dual Mechanism theory, exposure to regular and irregular verbs should generate different types of ERP: regular couples should elicit an effect similar to that of repetition, since the recognition of the base form is facilitated by the pre-activation of the root in the past participle; on the contrary, irregular pairs should have not to give rise to any repetition effect,

since irregular forms are represented as separated lexical entries. The results confirmed the expectations: similarly to other data on repetition priming, regular pairs elicited a N400 component, which was not found on irregular pairs.

Newman, Ullman, Benches, Waligura and Neville (2007) conducted an experimental study on English, based on the detection of ERP during a task of correctness ratings on sentences. Within the experimental sentences, regular and irregular verbs in the base form were inserted, instead of the past participle forms required by the context. The authors also included sentences containing violations of the syntactic structure. Sentences containing regular verbs elicited a LAN followed by a positive component, while only a positive component was detected on sentences containing irregular verbs. Sentences with violations of syntactic structure elicited a LAN similar to the one obtained on regular verbs. According to Newman et al., these results not only confirm the involvement of different mental processes for processing of regular and irregular words, but seem to indicate the existence of shared neurocognitive substrates for the processing of regular morphology and syntactic structure of sentences .

Brain imaging techniques involve various instruments which can be used to investigate cognitive processes from different perspectives: Electroencephalography (EEG), based on the recording of electric signals from the brain; Magnetoencephalography (MEG), which is used to detect magnetic fields generated by the electrical activity of the brain; Positron Emission Tomography (PET), which detects changes in the cerebral blood flow; Magnetic Resonance Imaging (MRI or fMRI) which uses the magnetic properties of atom nuclei, obtaining detailed images of brain anatomy. Jaeger, Lockwood, Kemmerer, Van Valin, Murphy and Khalak (1996) used a brain imaging technique (PET) in an experimental task in which subjects had to read aloud the base forms of real or novel regular and irregular verbs of English, and then had to produce the past participle of these verbs. The data showed that different types of verbs determined the activation of different cortical areas: regular verbs activated the left dorsolateral prefrontal cortex and left anterior cingulate gyrus, while irregulars activated the middle temporal gyrus and left superior frontal gyrus. However, Joanisse and Seidenberg (2005) underlined that, in the experiment of Jaeger et al., regular and irregular verbs were presented during different trials,

leading to redundancy effects due to the higher morphological homogeneity of regular verbs.

Beretta, Campbell, Carr, Huang, Schmitt, Christianson and Cao (2003), employed an event-related fMRI during an experiment of production of inflected forms of German verbs and nouns, and found a greater activation with responses on irregular forms, and a left lateralization of regular processes.

In a PET study, Indefrey, Brown, Hagoort, Herzog, Seitz and Sach (1997) also found a dissociation in the responses to regular and irregular verbs of German, but their results are partially conflicting with those of Jaeger et al., in that they reveal that dorsolateral prefrontal area is more activated by irregular verbs.

Rhee, Pinker and Ullman (1999) used MEG to record the magnetic fields of brain regions activated during an experiment of production of past participles of regular and irregular English verbs. Dipoles were identified in the temporo/parietal left regions (between 250 and 310 ms) both for irregular and for regular verbs, but only regular verbs activated dipoles in left frontal regions (between 310 and 330 ms). In a similar production experiment with fMRI, Ullman, Bergida and O'Craven (1997), found greater activation in the inferior frontal

gyrus and caudate nucleus during the processing of irregular verbs.

Dhond, Marinkovic, Dale, Witzel and Halgren (2003), used MEG during an experiment of production of English past participles, and found activation of the same cortical areas for the processing of regular and irregular forms. However, irregular verbs elicited a greater activation in left occipitotemporal cortex, around 340 ms, while regulars determined an increase in activation of the left inferior prefrontal regions (around 470 ms).

De Diego Balaguer, Rodriguez-Fornells, Rotte, Bahlmann, Heinze and Munte (2006) reported data of an fMRI study on Spanish verbal system, based on the production of inflected forms of regular and irregular novel verbs. The results revealed differences in the patterns of activation of brain regions for regular and irregular verbs: areas related to grammatical processing are activated by both types of pseudo-verbs (left opercular inferior frontal gyrus), but several areas of the prefrontal cortex were selectively active in production of irregulars (bilateral inferior frontal area and dorsolateral prefrontal cortex); regular verbs showed a stronger activation in areas related to grammatical processing (anterior superior temporal gyrus/insular

cortex) and to phonological processing (left hippocampus).

All the findings described above seem to indicate fundamental differences in the topography of neural substrates for regular and irregular forms, probably corresponding to the distinction between rule-based combinatorial processes for regular forms and lexically stored entries for irregular ones.

1.12 Connectionist models

Despite the impressive amount of experimental data in favour of a dissociation between the cognitive processes involved in lexical access to regular vs. irregular forms, it is important to consider some data bringing to different conclusions.

Some studies on German (Smolka et al., 2003; Smolka, Zwitserlood and Rösler, 2007) and French (Meunier and Marslen-Wilson, 2003) reported a priming effect on both regular and irregular past participles, preceded by the infinitive of the verb. Pastizzo and Feldman (2002) showed that the magnitude of the priming effect on the recognition of past participles preceded by the base form of the same verb is directly proportional to the orthographic overlap between prime and target. Similar conclusions were reached by Feldman, Kostic, Basnight-Brown, Durdevic and Pastizzo (2010), in lexical decision with masked priming and cross-modal priming experiments, where the attenuated facilitation on irregular prime/target pairs was attributed to their lower degree of ortographic overlap. The morphological nature of facilitation effects on both regular and irregular pairs was confirmed, by the

interference observed on orthographic non-morphologically related pairs.

Baayen et al. (1997; 2003) found that frequency was a good predictor of response latencies for singular and plural forms of both regular *-s* and irregular *–n* Dutch nouns. These findings were interpreted as confirming that two parallel routes of lexical access, the decompositional route and the direct access route to whole form, are available for the processing of all inflected words.

Cortese, Balota, Sergent-Marshall, Buckner and Gold (2006) reported data on patients with Alzheimer dementia in a task of production of English verbal forms. Their results indicated that both regularity and phonological/orthographic consistency of inflectional patterns influenced performances of patients. The authors suggested that the deficit on irregular verbs shown by patients with AD can be explained on the basis of a deterioration in attentional capacity. This deficit would result in a difficulty at avoiding interference by phonologically similar high frequency verbs (enemies) during the processing of irregular forms: the high number of enemies, considered an index of low phonological consistency, would predict deficit on irregular verbs better than regularity.

In a research on a group of ten patients with Broca's aphasia, Bird, Lambon Ralph, Seidenberg, McClelland and Patterson (2003), argued that the benefit reported by Ullman et al. (1997) on irregular as compared to regular verbs does not depend on a separation between two different processing systems, but rather on the phonological features of the experimental stimuli, as emerged from a closer analysis.

In an experiment of sentence completion and repetition, the authors observed that the difference between regular and irregular verbal forms disappeared when monosyllabic words were used. In addition, further analysis revealed that both repetition and reading could be influenced by effects of word frequency, imageability and number of consonants at the beginning and at the end of the root. Finally, in a same/different decision task, patients showed difficulties in distinguishing regular past participles from their roots, but the same difficulties appeared on pairs with inconsistent phonological differences, such as *chess/chest*. This interpretation was extended to regular stimuli, presenting often having phonological differences between root and past participle, when compared to irregular couples. Bird et al. (2003) attributed the processing of verbal forms to a single

mechanism, and therefore put into question the conclusions by Ullman et al. (1997), that specific disorders of language can highlight a basic dissociation between regular and irregular processes. Braber, Patterson, Ellis and Lambon Ralph (2005) conducted further analyse on errors made by patients in the three experimental tasks by Bird et al. (2003). The errors were based on a tendency to simplify the phonological form of the target, confirming that the impairment on regular forms might be ascribed to a more general phonological impairment, which is sensitive to phonological complexity. Lambon Ralph, Braber, McClelland and Patterson (2005) reported further evidence of the existence of a phonological complexity effect, putatively sensitive to factors such as the presence of consonant clusters (sequences of consonant with no intervening vowels), or stress position.

Pinker and Ullman (2002b) recognized the validity of the analysis made by Bird et al. (2003), and argued that irregular verbs used in the experiment were characterized by a mapping between base form and past participle that was more complex than in verbs used in previous studies, and that many regular verbs presented phonological similarities to irregular roots,

which could make them more likely to be stored and so to be insensitive to ungrammaticality effects. Furthermore, Pinker and Ullman (2002b) criticized the comparison between the responses given by patients on regular verbs and those on phonological competitors pairs, such as *chess/chest*, because only a group of patients gave random responses on both types of stimuli, while other patients showed more problems with regular verbs, accordingly with previous data.

Joanisse and Seidenberg (2005) reported data from a study in which fMRI was used during a production task of regular and irregular past participles of English verbs or pseudo-verbs. Regular and irregular verbs elicited the same activation in the posterior temporal lobe of both hemispheres, whereas left and right inferior frontal gyrus received greater activation for regular verbs and pseudo-verbs than for irregular forms or pseudo-forms. Further analyse showed that irregular verbs phonologically similar to regular ones (such as sleep/slept), which were defined "pseudo-regular verbs", generated a pattern of activation similar to regular verbs and different from fully irregular verbs (such as take/took). The authors interpreted these findings as demonstrating that the pattern of activation of cortical areas was determined by the phonological

features of verbs, rather than by their morphological regularity. Similar conclusions are reached by Desai, Conant, Waldron and Binder (2006), who observed that reading or production of the past participle forms of regular and irregular verbs, balanced for phonological complexity, generated the same type of activation, and that the activation of specific brain areas during the processing of verbal forms is determined by the complexity of the morpho-phonological mapping between base and inflected form.

However, most part of the contributions in favour of single route theories is based on simulations of the language acquisition processes through the use of computational models, such as neural networks. According to the connectionist approach (Elman et al. 1996; Rumelhart and McClelland 1986, Quartz and Sejnowski, 1998), linguistic processes are reproducible through associative networks that operate without the use of symbolic rules. The first attempt in this direction was made by Rumelhart and McClelland (1986) with the previously mentioned Pattern Associator, consisting of a two-layer network, one for input and one for output. Each unit of the network is called "node", and is connected to the other units through connections of different weights. When a word is introduced within the

network, it is analyzed in its phonological components, each of which is transmitted to the corresponding network node. The activation spreads through the nodes until the more compatible output unit is reached. The pattern of activation through the nodes depends on the weights of the connections, which gradually change during the training phase. The training consists in presenting the network with verbal roots as inputs and their past tense forms as outputs, changing the weights of connections after each session to improve the network performance. When the network captures the phonological relations between roots and past tense forms, it is also able to generalize the acquired pattern on new roots phonologically similar to the training roots.

Rumelhart and McClelland used a similar network to simulate the acquisition of English past tense. The network was trained with a set of regular and irregular verbs, showing, during the training phase, a tendency to over-regularize irregular roots. At the end of training, the network had achieved a fair degree of generalization, catching even some sub-regular patterns within irregular verbs. For this reason, Rumelhart and McClelland argued that their network

could simulate in a satisfactory way the process of acquisition of past participle by children.

Plunkett and Marchman (1991), argued on the efficacy of a simulation through neural networks when referred to the acquisition of an inflectional system such as the Arabic plural system. The peculiarity of this inflectional system is the presence of a restricted regular class and a large number of discontinuous ("broken") inflectional classes, each characterized by strong phonological constraints. Plunkett and Marchman underlined the difficulty of two layers networks (similar to the one of Rumelhart and McClelland, 1986) in learning the default class, due to the prevalence of irregular classes. A considerably less complex situation is exhibited by the English verbal system, where most verbs belong to the default class. Using a corpus of English regular verbs, Daugherty and Seidenberg (1992) achieved the 94% of accuracy of the responses given by the network on regular novel roots, demonstrating that a connectionist model is able to learn a default class when it is properly trained on clearly structured real examples. The problem still remains open in relation to languages such as Arabic or Italian, which have a number of irregular classes, the first on nouns, the second on verbs.

The limits pointed out by Prasada and Pinker about the network of Rumelhart and McClelland were examined by Hare, Elman, and Daugherty (1995), who attributed these difficulties of the network to the simplicity of its structure relative to the complexity of the processes to capture. Rumelhart and McClelland's pattern associator was inspired by the Rosenblatt's perceptron (1962), consisting of only two levels of units. A limit of this type of network is that it is not able to find a decision boundary for non-linearly separable problems. Hare and colleagues used a three layers network, provided with a level of "hidden" units (Minsky and Papert 1969), which re-represent stimuli received in input into a new space, facilitating the achievement of the solution. The authors hypothesized that, since the network is sensitive to phonological features, it is possible to arrange a training set which allows the model to acquire groups of phonological sub-regularities. A default class, whose members may not exhibit any phonological regularity, is necessary to classify verbs which do not fall within other phonological classes. The hypothesis by Hare, Elman, and Daugherty arises from the so-called "Distributional Asymmetry" theory, which states that the existence of a default class cannot be attributed to the higher type-frequency of regular

patterns as compared to irregular ones, but rather to the fact that irregular patterns are often much more constrained into phonological clusters, occupying well-defined positions in the phonological space of a language, whereas the generalizability of regular patterns is due to their more distributed and less phonologically structured character (Berent, Pinker, and Shimron, 1999).

Hare, Elman and Daugherty (1995) conducted a simulative study on the verbal system of Old English (OE). OE was characterized by a "weak" default class: although the process of suffixation of the past tense, derived from German, had replaced the indo-european method based on the change of the thematic vowel, it became dominant on low-frequency verbs, while most of high frequency verbs preserved the indo-european pattern. Hare et al. used a three layer network, with: i) a level of input units consisting of representations of words containing strings of letters that corresponded to a specific VC or VCC configurations, ii) a hidden units level, and iii) an output layer based on the representations of six verbal classes, five corresponding to the inflectional classes of OE, the sixth corresponding to the default class, and including all combinations which did not fall into the other VC or

VCC classes. The network was trained in order to conduct a categorization task; then it was tested on a set of novel verbs which did not belong to any of the five inflectional classes. Some verbs were assigned to one class on the basis of phonological similarity, but most of them were assigned to the default category. Responses on items similar to the representations of the five classes in input level were always correct. The responses on the five classes were influenced by a distance effect, because the probability of a verb to be assigned to one of the classes decreased as it was less similar to a class representation. On the contrary, the same tendency did not emerge on the sixth class. The network was then tested on a task of production of inflected forms. The presentation of a stem that appeared to be compatible with two inflectional classes, could determine either the simultaneous activation of two classes in the output level (which was recorded as an error), or the activation of the stronger class. The choice of the default class, however, should have to occur regardless of the phonological similarity of the input with respect to the representations of the inflectional class. An interactive network, whose task was to determine the probability of a particular input to take a particular root inflection, received the output of

the feed-forward network and tested the compatibility of the verbal stem with competitor phonemes, discarding those contradictory and reinforcing the activation of those that were compatible.

The results were in line with expectations: the inflectional classes presenting a change in the thematic vowel were chosen on the basis of phonological similarity with the input, while the default class was chosen on verbs that were not compatible with the other classes. Only 9% of verbs with low similarity was also classified in non-default inflectional classes. Therefore, the results of the work of Hare, Elman, and Daugherty, seem to show that a multi-layer network is able to simulate the default mechanism, through the creation of phonologically well-structured inflectional classes and a default class provided with specific attribution criteria.

Clahsen (1999), argued that the *-ed* suffix cannot be regarded simply as a default, because it represents a specific syntactic element of the English language. He also observed that the network by Hare, Elman, and Daugherty does not consider cases of systematic irregularities based on suppletive forms of the root (e.g. *go/went*). Berent, Pinker and Shimron (1999) also criticized the simulation mode by Hare, Elman, and

Daugherty because the network was provided with a superimposed inflectional rule. This would make the results insufficient to offer an alternative interpretation to symbolic theory, because they do not demonstrate that the default class can be acquired independently of innate mechanisms.

Hare and Elman (1995) also deepened the investigation on the historical development of OE. The evolution of this language, indeed, was characterized by a general tendency towards regularization of irregular roots, determined, in turn, by the adaptation of minor strong patterns (based on the change of the thematic vowel) to the weak pattern based on the suffixation, shared by the majority of verbs, predominantly of low frequency. The movement of strong classes towards the weak class was determined by the high generalizability of the suffixation pattern, in opposition to the specificity of phonological constraints shared by the members of the strong inflectional classes.

Hare and Elman tried to simulate the diachronic evolution of OE through the use of multiple networks: the output given by a network was submitted to the next network as a "teacher". The goal was to demonstrate that the process of regularization

depended on the frequency of verbs, and on the extension of the strong classes.

In accordance with expectations, only the most frequent and phonologically well structured strong classes were insensitive to the regularization process during the simulation. There was a general movement of strong toward weak classes, but, in some cases, the network generalized a strong pattern on a weak verb, on the basis of phonological neighbourhood.

A limitation of computational models of language processing is the lack of the semantic representations of words: most of these models are conceived just for the manipulation of phonological representations, so they can hardly reach the right response on some particular forms, as it is the case of homophones. Another problem is the direct access, namely, the possibility by human speakers to access inflected forms directly, without applying the inflectional rule on base forms. McWhinney and Leinbach (1991) se up a connectionist network provided with a semantic component in addition to the phonological one, which allowed the network to correctly process homophones. Hoeffner (1992) designed a model containing the representations of the semantic nuclei of verbs of the training phase and the representation of the inflectional

suffixes at the input level. This structure allowed the network to make a distinction between inflected forms of a verb, linked to the same meaning but having two different suffixes. Different specificities of the production of verbal inflected forms were investigated:

1. the semantic component was useful to process homophones with different meanings;
2. it was possible to simulate a direct access, by directly inserting an inflected form in the network;
3. during the training session, the network was able to reproduce the level of response accuracy similar to that shown by children in acquiring language (after a certain number of sessions the network reached high percentage of correct answers on irregular forms, then showing a sudden deterioration due to the generalization of the regular pattern, which tended to disappear toward the end of training);
4. among the errors made by the network, there were cases of double-marked forms (eg. *wented), also frequently observed in the responses by children;
5. the network was able to assimilate phonological sub-regularities through irregular verbs;

6 finally, the network showed frequency effects similar to those seen on humans.

Plunkett and Marchman (1991, 1993) tried to imitate the acquisition of past tense by children, by demonstrating that the profile of errors made by children could be explained by an underlying system which systematizes the relationship between the base form of a verb and the past tense form. The rate of insertion of new verbs in the network during the training session was varied at different stages, in order to replicate the U-shaped curve process. The order of insertion of verbs was determined on the basis of token frequency. Comparing the results of the simulation to those observed on a child, Adam, at different phases of language acquisition (Marcus et al., 1992), Plunkett and Marchman concluded that their model was able to capture all the aspects of the acquisition of the past tense.

Marcus (1995) strongly criticized the results by Plunkett and Marchman, stating that the analysis of the data was subject to distortions, especially in the comparison between the network and Adam. A new analysis of over-regularizations by Adam shows that, despite regular inputs by adults were much less frequent than

irregular ones, the child reached a higher level of over-regularizations than the network, which showed, instead, a greater tendency to irregularizations. Plunkett and Marchman argued that generalization is virtually absent when the contribution of regular models is less than 50%, but the data on Adam are clearly against this statement, confirming the hypothesis of the intervention of abstracts mechanisms in language learning by children. According to Marcus, it seems that the PM model was induced to over-regularizations, since the stage in which the network started to over-generalize coincided with an abrupt acceleration in the rate of insertion of irregular verbs in the network. In addition, over-regularizations by the child continued until he reached a vocabulary of about 400 verbs, while the network stopped suddenly to over-generalize when it learned the last irregular verb.

Marcus noted that, while some connectionist models (Rumelhart and McClelland, 1986) produce over-regularizations more similar to those made by children, involving more often irregular participles that require a change in thematic vowel, rather than those with no vowel change, while PM model, on the contrary, over-regularizes more often verbs of the second type. Moreover, unlike the children, the model produces

double-marked forms (*past+ed*) more often than *root+ed* errors. Finally, the PM network tends to make more irregularizations than over-regularizations.

Plunkett and Marchman (1996) responded to the criticism by Marcus, arguing that the main objective of their model was to study the extent to which structural and qualitative changes in the vocabulary lead to changes in the way the network establishes relationships between verbal stems and past participles, and that the results can hardly be considered an exhaustive reproduction of the language learning process by children, mainly because of the constraints imposed on the network: as the limited vocabulary, the inability to process homophonic roots, and the fact that the phonological representations did not interact with other components of language. Nonetheless, they argued that the behaviour of the network can be equally considered a contribution to the understanding of some typical behaviours of children at certain stages of their language acquisition.

Sub-symbolic perspectives on children's behaviour can be based on the assumption that, when they start to try to communicate, they possess a limited mental lexicon, a vague idea of syntax and minimal phonological representation of the words. In such a context, children

work on associations between words and their hypothesized meanings. This mechanism is actually very similar to that used by a neural network in the learning phase. Plunkett and Joula (1999) used the term "hypothesis generator" to refer to mental processes developed by the children. They tried to reproduce the U-shaped curve observed during nouns and verbs acquisition, through a neural network trained to produce inflected forms of regular and irregular nouns and verbs. Plunkett and Joula attempted to answer the criticism which Marcus (1995) addressed against the work of Rumelhart and McClelland (1986), that this process was irreproducible because of the rarity of irregular nouns. During the training phase they gave the network a number of irregular nouns and verbs significantly higher than regular ones, trying to compensate the numerical inferiority of irregular with respect to regular patterns. With such a measure, Plunkett and Joula seem actually achieved their goal: the network begun to over-regularize nouns before verbs, and made also more errors on nouns. This result is partially consistent with the data presented by Marcus (1995), according to which all children made more errors with nouns. In addition, both network data and those on children show a lower percentage of

errors on high frequent irregular forms and a rapid acquisition of regular nominal inflectional patterns, probably due to the minority of irregular nouns.

The network made a small amount of errors of non-root change on verbs that ended in alveolar consonants, and fewer over-regularizations on irregular verbs that did not involve changes in the root in the formation of the past tense. These results are consistent with those obtained by Marcus (1992).

Plunkett and Bandelow (2006) used the same model used by Plunkett and Joula (1999), to simulate the effects of random damages on a network with respect to the processing of regular and irregular nouns and verbs. Damages were determined by the random removal of individual connections. The authors observed a general deterioration of the network performance, directly proportional to the severity of the lesions, and a tendency of irregular forms to be more impaired than regular ones. Such a result was interpreted as showing that a single mechanism model is sufficient to explain the double dissociation found on aphasic patients.

The acquisition of nominal inflection was investigated by Nakisa, Plunkett and Hahn (1998) in two simulations on a connectionist network trained to produce plural

forms of German. In the first simulation, at the end of the training phase, the network was able to produce between 70% and 80% of correct answers. In the second simulation, the *–s* suffix was removed from the network and applied only to items phonologically distant from other instances of singular nouns, trying to define a default class. The authors noted that such a device did not determined an improvement in network performance, demonstrating that a single mechanism is sufficient for learning the inflection of regular and irregular nouns.

Clahsen argued that the apparent effectiveness of the model proposed by Nakisa et al. is due to the fact that the German plural system is dominated by a majority of irregular patterns. Moreover, the choice of attributing the *–s* suffix to nouns phonologically distant from the others, is based on the wrong assumption that all the German nouns marked by the *–s* suffix of the plural are phonologically distant from the others. Finally, the elimination of all the nouns in *-s* in the training phase of the second simulation seems an unrealistic manipulation of the learning process of the network.

Westermann and Goebel (1995) proposed a simulation on German verbs, designed to reproduce the functioning of the symbolic model through the

implementation of two different components, a combinatorial system and its associated vocabulary. The network was able to generalize the n-suffix on the basis of phonological similarity, and the t-suffix by default, replicating the data on human subjects (Clahsen 1999). Goebel and Indefrey (1998) applied the same criterion in a simulation based on the plural of German nouns. The network achieved partial success on irregular patterns, while it was not able to generalize the s-suffix, in contrast with data on speakers of German (Marcus et al., 1995). Goebel and Indefrey attributed the contrasting results to the low frequency of plurals in *-s.*

Moscoso del Prado Martin, Ernestus and Baayen (2004) attempted to reproduce the effects of type/token frequency by implementing three Simple Recurrent Network (SRN) trained on the production of past tense in Dutch. The network performance was comparable to the one observed on human participants: the network produced a large number of regularization of pseudo-verbs, and irregularized only pseudo-roots closely similar to existing irregular verbs. The authors concluded that the generalization of inflectional patterns can be analysed in terms of analogical similarity. Similar conclusions were reached by

Keuleers, Sandra, Daelemans, Gillis, Durieux and Martens (2007) after a simulation where it was observed that Dutch plural formation is based on analogy instead of rule, and that non-phonological information (e.g., orthographical information) significantly improves the accuracy of the model in plural inflections of Dutch nouns, with respect to a purely phonological model.

According to Joanisse and Seidenberg (1999), the split between deficits on regular and irregular processes is due to damages to phonological vs. semantic systems: a deficit in the phonological system would affect the processing of inflected forms of new verbs (as wug/wugged) because of the inability to access the semantic representation, which makes it necessary to access the phonological representation of the verb. On the contrary, damages to the semantic system would affect the production of irregular inflected forms, since a past participle phonologically idiosyncratic form (e.g. take/took) can only be processed through the access to the semantic representation of the verb[1]. The authors tried to show the validity of their model by building up a

[1] For a further review on the role of semantic factors on the processing of regular and irregular verbs, see also Kim, Pinker, Prince and Prasada (1991); Ramscar (2002); Gordon and Miozzo (2008); Woollams, Joanisse and Patterson (2009).

three level network, with a semantic input system, in which the meaning of each word was represented by a node, a phonological input system containing a distributed representation of word sounds, and a phonological output system containing the same representations of the phonological input system.

After having trained the network to product the past tense of English verbs, the authors simulated lesions to the semantic and the phonological output systems, by damaging the connections of these systems with the cleanup unit, which helped the network to encode information. In this way, they simulated deficits similar to those shown by patients with Broca's aphasia, through damages to the phonological system, and disturbances in the production of irregular forms through damages to the semantic system. Joanisse (2004) implemented a network trained to associate the phonological representation with the meaning of verb forms, and to produce the past tense. This model was designed to simulate the language acquisition by children with SLI and to test the hypothesis of deficits in perception. The network was trained to produce and recognize forms of the present indicative and the past participle, by receiving input from both the semantic and phonological system. In one session, the network

received a normal training, showing slightly longer learning curves for irregular verbs, and achieving good levels of accuracy at the end of training. In a second session, during the training phase, the authors provoked damages in phonological representations in input level, thus simulating a perceptual deficit. At the end of training, the network showed problems similar to those characteristic of the SLI: difficulty to learn past tense inflectional patterns, lack of generalization of inflectional patterns on new verbs and low number of over-regularization.

According to Joanisse, these results seem to demonstrate again the possibility to reproduce the dissociation between regular and irregular processes through a single mechanism based on a connectionist network.

More recently, the simulation study of Keuleers and Daelemans (2007) highlighted some methodological limits of traditional computational models for the simulation of language processing. They used a memory-based learning model (MBL) based on an algorithm that, instead of operating explicit generalizations, compared new instances with instances seen in training, which had been stored in memory. The MBL by Keuleers and Daelmans was

based on a version of the *k* nearest neighbours approach, which assigns the class to a novel item on the basis of the most frequent class of its most similar neighbours (for example, a MBL with a *k*=7 criterion chooses the most frequent pattern between the seven more similar neighbours). The model was tested on a *lexical reconstruction* task, in which the plural forms of real English nouns had to be predicted, treating them as new materials and by generalizing inflectional patterns on the basis of known verbs. Then the model was tested in two *pure generalization* tasks, in which it had to predict the plural forms of a list of nonce nouns used by Baayen et al. (2002), and then to predict the plural forms of a list of novel nouns used in an experiment by Keuleers et al. (2007). The expectancy of the authors was to find different patterns of results in the two tasks (lexical reconstruction and pure generalization). They considered exception an irregular form with an infrequent pattern, or with a frequent pattern but in a hostile neighbourhood (neighbours following different inflectional patterns). The MBL was expected to successfully predict low frequency exceptions with a low value of *k*, or to be better in predicting highly frequent exceptions with a high *k* value. The results of the three simulations showed different optimal *k* values

across the different tasks: in the lexical reconstruction task, a low *k* value gave rise to higher accuracy. The same optimal *k* value determined a lower accuracy in the pure generalization tasks. This pattern led the authors to conclude that predicting exceptions could be harmful in simulating language processing, and that a good performance obtained by a simulation of language processing does not necessarily correspond to a good imitation of human speakers behaviour.

1.13 The morpho-phonological account

The approach on lexical access for morphologically complex words of Marslen-Wilson, Tyler and colleagues (Marslen-Wilson and Tyler, 1997; Marslen-Wilson and Tyler, 1998; Marslen-Wilson and Tyler, 2003; Marslen-Wilson and Tyler, 2007; Tyler, Marslen- Wilson, and Stamatakis, 2005b; Tyler, Randall, and Marslen-Wilson, 2002b; Tyler, Stamatakis, Post, Randall, and Marslen-Wilson, 2005a; Tyler et al., 2002a) is based on the distinction between different mechanisms for morpho-phonologically decomposable forms and whole form-based representations. The approach, though being in agreement with traditional Dual Mechanism model and Declarative-Procedural model with respect to their basic predictions, takes an original position, in that it

doesn't hold that a grammatical morpheme is necessary to determine the decomposed access to an inflected form. Marslen-Wilson, Tyler and colleagues claim that it is possible to recognize morpho-phonological features which act as cues for the presence of a potential inflectional suffix, thus determining the processing of words through a *stem+affix* analysis. These property was defined *inflectional rhyme pattern* (IRP). For the English verbal system, it consists of a final coronal consonant (/t/, /d/, /s/, /z/) that agrees in voicing with the preceding segment (as in filled, mild, or nilled).

The most interesting result was obtained by Tyler, DeMornay-Davies, Anokhina, Longworth, Randall and Marslen-Wilson (2002) in a same/different judgement task, in which patients had to decide if pairs of spoken stimuli were the same or not. Patients with grammatical deficits were impaired in responses to regular past tense/stem form pairs, but a similar (though smaller) impairment was observed on all pairs containing inflectional affixes, such as pairs containing pseudo-regular forms (e.g. *jade/jay*) or regular non-words (e.g. *kade/kay*). Putative non-morphological segmentation effects were excluded by testing pairs such as *claim/clay* (in which the final phoneme of the

first member had been deleted), which were responded correctly. A similar pattern of responses was obtained on a same/different judgement task completed by wealthy English adult speakers in an fMRI study (Tyler, Stamatakis, Post, Randall and Marslen-Wilson, 2005a). These results confirm that any item having the critical diagnostic property activates the segmentation into stem plus affix.

Post, Marslen-Wilson, Randall and Tyler (2008), found further support for their model in a same/different judgement task on auditory stimuli, where the agreement in voicing between the coronal consonant and the preceding segment, in regular, pseudo-regular and non word pairs was manipulated. They found slower responses on regular inflected pairs and a smaller but significant inhibitory effect on pseudo-regular and non word pairs, which was not observed on monomorphemic pairs with the coronal consonant of the first member not agreeing in voicing with the rhyme. These results seem to confirm that the rhyme pattern is the critical feature for the segmentation of inflected and pseudo-inflected words. The authors outlined that the status of IRP interacts with the processing of irregular forms: irregular forms such as *slept*, which are phonologically similar to the regular

past tense *stepped*, trigger an attempt at morphological decomposition, determining slower responses. This interpretation is compatible with fMRI findings by Joanisse and Seidenberg (1999) in a verb production task, in which they observed different activation effects in both left and right frontal regions between regulars and irregulars, but in which a pattern of activation similar to that of regulars, for a subset of irregulars similar to regulars, such as *slept*, emerged. Such an interpretation would be confirmed by data from experiments of lexical decision with priming, in an ERP study by Kielar and Joanisse (2010), in which it was observed that irregular pairs showing a partial regularity, such as *slept/sleep*, elicited an N400 priming effect similar to that elicited by regular pairs, while a lower effect emerged from vowel change irregular pairs (e.g. *sang/sing*). Kielar, Joanisse and Hare (2008), found similar results in two lexical decision experiments with masked and cross-modal priming, by manipulating the prime/target ISI (Inter Sstimulus Interval). They observed a priming effect only on regular and weak irregulars in the masked priming experiment. When the ISI was increased, strong irregular past tense forms primed also the corresponding present tense forms,

revealing a priming effect based on a convergence of orthographic, phonological and semantic relationships.
Justus, Larsen, De Mornay Davies and Swick (2008), in an ERP study based on a lexical decision task with priming, found that strong irregular pairs, such as *spoke/speak*, elicited an N400 priming stronger than the one observed on both regular and weak irregular pairs such as *spent/spend*. In a priming experiment on patients with damage to anterior regions of the left hemisphere, Justus, Larsen, Yang, De Mornay Davies, Dronkers and Swick (2011) did not find priming effects on regular past tense/present tense pairs. Nevertheless, they observed that the dissociation between regular and irregular verbs was continuous rather than categorical: the priming effect on weak irregular pairs was intermediate between regulars and strong irregulars. Furthermore, control pairs based on orthographic-phonological overlap, such as *barge/bar* or *bead-bee* (pseudo-past condition) showed the same pattern of results observed on regular pairs. The authors claimed that results on pseudo-past pairs are in line with the morpho-phonological account of Marslen Wilson and Tyler (2007), but all the results on regular, pseudo-past an orthographic-phonological pairs may only be explained by a single mechanism account which

hypothesizes that inflectional processes are linked to phonology. The "dissociation" between regular and irregular verbs was interpreted by Justus et al. (2008) as a continuum which goes from a maximum level of phonological-orthographic relationship to a maximum level of semantic relationship between present and past tense forms.

1.14 Lexical strength and multiple correspondences

Bybee (1991; 1995) introduced the concept of "lexical strength", which refers to the likelihood that the direct vs. decomposed access for morphologically complex words depends on the word frequency, which determines the strength of a word representation. According to this hypothesis, each time a word is processed during recognition or production, the correspondent string of letters is compared with an existing mental representation. If the two items match, the representation is strengthened, while if there is only a partial overlap at the semantic and/or phonological level, a lexical connection between their representation is created. Only the most frequent forms are represented in the mental lexicon, independently from their being regular or irregular, while low-frequency words are processed through a separated activation of stems and affixes. In this perspective, Bybee's hypothesis shares predictions with both single mechanism and dual mechanism theories, as it is the case for a model introduced by Stemberger, who studied inflectional processes by means of the analysis of overtensing errors in spontaneous speech by adults and children (Stemberger, 1982, 2002, 2007;

Stemberger and Middleton, 2003). Overtensing errors are based on the production of the past participle of a verb instead of the infinitive form. Stemberger observed that overtensing errors involve irregular more often than regular forms, and vowel change more often than suffixed forms, probably due to phonological confounds rather than regularity. According to the author, the data on overtensing errors demonstrate that it is not possible to attribute the processing of regular inflected forms to a system based on the use of morphological rules, and the lexical access of irregular forms to a system of interconnection based on phonological features. According to the author, it is necessary to consider the processing of both regular and irregular inflected forms as the result of an overlap between morphological and phonological processes.

Stemberger framed his hypothesis within the "Optimality Theory" (Prince and Smolensky, 1993; Benua, 1997; Bernhardt and Stemberger, 1998; Smolensky, 1999), which replaces rules based on symbols with constraints based on symbols. According to this hypothesis, phonological generalizations are not made on the basis of rules, but on the basis of phonological constraints, whose goal is to determine the *optimal* pronunciation of a word. Some of these

constraints are often violated, while other are more important and cannot be violated. In this perspective, morphological relationships are modulated by phonological constraints, and may be seen as correspondences between surface forms defined as output-output correspondence, (constraint of output-output faithfulness, OO-F). The notion of OO-F was developed by Burzio (1998; 2000; 2002a; 2002b; 2003; 2004), who stressed the need to substitute the traditional "Word formation rule" (WFR) with this new concept. The WFR allows to analyze only the syntagmatic relations between allomorphs, such as /permit/ permi-t → [t]-ed, but not paradigmatic relations, as that between the forms go/went, or quasi-syntagmatic relations, as keep- t →kep-t.

The model proposed by Burzio establishes that words are not stored as whole forms or decomposed forms on the basis of their regularity/irregularity, but that they are represented within a system of connections between words and word fragments, in which the morphological relationships between allomorphs are the result of the strength of the connections between the surface forms of the words themselves.

According to Tabak, Schreuder and Baayen (2010), the data presented by Stemberger (2002; 2007) and by

Stemberger and Middleton (2003) are compatible with the "Words and Paradigms" theory (Matthews, 1974; Aronoff, 1994; Beard, 1995; Blevins, 2003), which assumes that words are the basic units of the lexicon, and that the processing of morphologically complex words is co-determined by the interaction between paradigmatically related inflected forms. The paradigmatic organization of the lexicon would be corroborated by the fact that frequency effects involve both irregular and regular inflected forms (Baayen et al., 1997; 2003; Tabak et al., 2010).

1.15 Full decomposition single route models

Stockall and Marantz (2006) proposed a single route model for the processing of morphologically complex words, based on the assumption that all forms, even irregular forms as *give/gave* or *teach/taught,* are processed through a parsing in stem and affixes. The model was refined on the basis of data from two lexical decision experiments with cross-modal priming, in a MEG study.

In the first experiment, English infinite/past participle pairs of irregular verbs were used, with the past participle presented in prime position. The responses on morphologically related pairs were compared to

those related to pairs of orthographically similar stimuli. However, the facilitation emerged only on pairs such as *gave/give*, which shared a greater amount of orthographic material, but not on pairs like *taught/teach* The second experiment involved both regular and irregular verbs, presented in the reverse prime/target order that that of the first experiment. The results of the experiments show that both pairs of irregular and regular forms determined an M350, which reflects the activation of the root (Pylkkänen et al. 2002; Stockall et al., 2004), and also appears in presence of morphological relations between stimuli (Pylkkänen et al., 2004). According to the authors, this outcome shows that the verbal root is activated both by a regular and by an irregular past participle, and that the relationship between an irregular form and its infinite (e.g. *taught/teach*), cannot be considered as only semantic or phonological, because it is influenced by the same effects found on morphological related words.

In the second experiment, the infinitive preceded the past participle, and a facilitation was observed on both regular and irregular pairs. The authors emphasize that this finding contrasts with Allen and Badecker's (2002),

who found a facilitation on *taught/teach* pairs, but not on *gave/give* pairs.

A contradiction arises from the fact that pairs like *taught/teach* elicited a M350 (similar to other irregular pairs), but did not receive a facilitation from recognition of the target, which emerged only with the reverse presentation. Stockall and Marantz hypothesized that an irregular allomorph such as *taught* activates both the root TEACH and the specific irregular inflectional pattern. Instead, the presentation of the form *teach* in target position activates the root TEACH, but suffers from the competitive activation of the inflectional rule, resulting in longer reaction times. In the reverse order of presentation (*teach/taught*), the irregular pattern is not activated from the infinitive, and the past participle benefits from the facilitation due to the activation of the root.

A full decomposition model for lexical access was proposed by Smolka, Zwitserlood and Rösler (2007), who hypothesized that words are represented and processed through their constituents, and accessed through the activation of their meaning. Roots are not marked by grammatical category, and morphologically related inflected forms activate the same meaning. The speed of lexical access is influenced by the frequency of

both constituents and surface form: the frequency of constituents positively influences the speed and strength of activation of concepts related to the representation, while the form frequency strengthens the connections between the representations of the constituents, thus increasing the activation of concepts in the processing of existing words, and contrasting the processing of non-words.

1.16 Islands of reliability

As previously reported, Albright and Hayes (2002) developed a hypothesis which can be seen as an alternative to the symbolic approach, as it is based on the assumption that both regular and irregular forms are processed through the application of multiple phonological rules defining "Islands of reliability", sets of features which describe the morphological variations within certain inflectional patterns. This model re-examines the concept of rule from a new perspective, by postulating the co-existence into the same inflectional system of multiple probabilistic rules, whose activation is determined by phonological neighbourhood. Furthermore, Albright and Hayes (2003) make a distinction between their own concept of similarity, and the one considered by traditional

analogical models: the concept of "structured similarity", characterizing forms that are similar to each other on the basis of a fixed structural description, is opposed to the concept of "variegated similarity", characterizing forms that are similar to each other according to several aspects, such as the initial or the final segment of the stem. The use of a criterion of structured similarity allows to individuate a set of necessary and sufficient features defining the phonological space of a rule. Albright and Hayes (2003) tested a group of adult English speakers on two experimental tasks, modelled on the basis of the experiments by Prasada and Pinker (1993): in the first experiment, based on the "Wug" test (Berko, 1958), participants had to produce past tense forms of novel verbs given as pseudo-stems; in the second experiment, participants had to rate the acceptability of possible regular and irregular pseudo-past tense forms of the pseudo-verbs already seen in the Wug test. Responses given by participants were compared with the results of the acceptability rating tasks simulated on two different models: the first was based on a rule-based model which used an inductive learning to identify islands of reliability; the second was based on the General Context Model (GCM, Nosofsky, 1990), which

evaluated the likelihood of regular/irregular responses on the basis of the variegated similarity between stems. The result of the simulation on the rule-based model was the individuation of a set of multiple rules of different levels of generality and accuracy (accuracy corresponded to the ratio of cases where the rule correctly applies to cases where it potentially applies). Responses by the rule-based model were a good predictor of the responses given by subjects, which were coherent with the islands of reliability identified by the model. On the contrary, the GCM evaluated the global similarity between forms, failing to catch structured similarities, and overrating implausible responses on the basis of single pairs of highly similar forms. According to the authors, such data confirmed that speakers generalize morphological patterns on the basis of structural properties defined by probabilistic rules.

Ambridge (2010) used the core set of wug stems by Albright and Hayes in an experiment of acceptability rating for regular and irregular past-tense forms, on a group of children. The results showed an effect of similarity on irregular verbs, which did not interact with children's age. However, regular verbs showed a similarity effect in older children, but not in younger

ones, who had yet to recognize the regular inflectional pattern. According to the author, these data are incompatible with the predictions of dual mechanism model, while are interpretable on the basis of both single route models and multiple rules model (Albright and Hayes, 2003).

Chapter 2 .
Experimental background on the processing of Italian verbs

2.1 Introduction

A crucial property of the verbal system of Italian is the number of its sub-regular patterns, occurring in morpho-phonologically well structured and predictable linguistic environments. This property makes it difficult, for traditional Single and Dual Mechanism theories, to capture the processing mechanisms for Italian verbs.

The Italian verbal system is organized in three conjugations, marked by three different endings of the infinitive forms: *-are* (e.g. *amare*), *-ere* (e.g. *temere*) and *–ire* (e.g. *dormire*).

The first conjugation contains the largest number of verb types (72,4%, De Mauro et al., 1993); it is the most productive and regular class, and contains only four irregular roots: *andare* (*to go*), *dare* (*to give*), *fare* (*to do*) and *stare* (*to stay*). The second conjugation is the smallest class (less than 400 verbs, 16%; De Mauro et al., 1993); it includes the highest number of irregular verbs. The third conjugation is partially productive

(11,6%; De Mauro et al., 1993), and contains a small number of irregular verbs.

Italian irregular verbs include both idiosyncratic forms, such as *dire/detto* (to *say/said*), and groups of sub-regular verbs, which share morpho-phonological features and follow the same minor inflectional pattern: for instance, verbs like *spingere* (*to push*), *fingere* (*to simulate*) and *dipingere* (*to paint*), follow the same inflectional model for past participle (*spinto, finto* and *dipinto*) and remote past (*spinsi*, *finsi* and *dipinsi*). These sub-regular models are often based on the alternation between a major and a minor stem (e.g., *sping/spint*). They are different from idiosyncratic irregular models because they are at least partially predictable on the basis of shared morpho-phonological features.

The Dual mechanism theory is not sufficient to define a mental representation of sub-regular forms, which cannot be considered neither regular nor completely irregular. The data on the processing of regular and irregular verbs in Italian are often framed within alternative theories, which attempt to overtake the traditional dichotomic distinction between regular and irregular forms.

2.2 Behavioural data

Orsolini and Marslen-Wilson (1997) attempted to identify some phonological features of irregular verbs, such as consonantic segments placed at the end of each root. These segments may consist of: a vowel and the dental consonant */d/*, (like in *ridere* (*to laugh*)/ *riso* (*laughed*)), or a vowel and the nasal-dental consonant */nd/*, (like in *prendere* (*to take*)/ *preso* (*token*)), or a vowel and the dental consonant */t/*, (like in *trasmettere* (*to transmit*)/ *trasmesso* (*transmitted*)), or a vowel and the palatal velar consonant */g/*, (like in *leggere* (*to read*)/ *letto* (*read*)). The regularity of these phenomena, despite the existence of some "exceptions" (such as the regular verb *vendere* (*to sell)/ venduto* (*sold*)) suggests that Italian verbal system has a greater phonological complexity than English system.

In the cross-modal priming experiment, six categories of prime/target pairs were used:

1. past tense/infinitive form of a regular verb (*giocarono* (*they played*)/ *giocare* (*to play*);
2. past tense/past participle of a regular verb (*amarono* (*they loved*)/ *amato* (*loved*));
3. past tense/infinitive form of an irregular verb (*presero* (*they took*) / *prendere* (*to take*));

4. past tense/past participle of an irregular verb (*scesero* (*they went down*)/ *sceso* (*gone down*));
5. past tense/past participle of homographic roots with different meanings (*volò* (*he flied*)/*voluto* (*wanted*));
6. past tense/infinite form of semantically related verbs (*dissero (they said*)/ *parlare* (*to speak*)).

According to the symbolic approach, priming effect was expected to be strong only on pairs based on regular or irregular forms sharing the same root (conditions 1, 2 and 3). Forms of the same verbs but based on different roots (condition 3), should determine a weak priming effect, or no effect at all.

The results were partially contrasting with the expectations: a facilitatory priming effect was observed in the first four conditions and a weaker effect on the sixth condition, while an inhibitory effect was observed in condition 5. These data, although not contradictory with those obtained on English, are hardly interpretable within the Dual Mechanism approach, because they do not confirm a complete dissociation between regular and sub-regular patterns.

In the second experiment subjects had to produce the past participle of novel verbs, which had been created

on the basis of the similarity to existing 2nd or 3rd conjugation verbs. The level of similarity was defined according to three categories of phonological similarity to real verbs, similar to those used by Prasada and Pinker (1993):

- High similarity. The target showed a strong similarity to one or more irregular verbs based on the alternation between a major and a minor stem (**frendere*);
- Similarity of the root. The target was similar to the initial segment of one or more existing roots, and had a typical ending of the second conjugation of irregular verbs (**immundere*);
- Low similarity. The target did not show any resemblance to existing roots either at the beginning or at the end of the root, though being based on a combination of sounds still phonotactically acceptable in Italian (**maffecere*).

The results show a strong effect of class membership: the most part of regularizations involved pseudo-roots of the 3rd conjugation, while a lot of irregularizations were produced on the 2nd conjugation novel verbs. Furthermore, responses were influenced by

phonological similarity, since both regularizations and irregularizations decreased with low similarity pseudo-verbs. On the pseudo-roots of the 2nd conjugation, most of the irregularizations were observed, both in the condition of high similarity and in that of root similarity. Such a result is in contrast with data on English, where the irregularization rate decreased significantly in the second condition. This difference might be interpreted as confirming that Italian irregular patterns are more generalizable than English ones, given their phonological structure. A similar relation between types of responses and phonological similarity was observed relative to the rate of regularizations of 3rd conjugation pseudo-verbs, which decreased in the condition of low similarity.

A comparison between the results of the first and second experiment reveals several incompatibilities with the Dual Mechanism theory. The priming effect observed on irregular verbs in Experiment 1 seems to demonstrate that such inflected forms are generated through the application of rules, while the data from the production task suggest single representation of the same forms (irregularizations were affected by phonological similarity). A similar pattern of results was observed on regularization of pseudo-roots similar to

regular verbs. In light of these findings, it seems difficult to refer to a rigid dichotomy between regular and irregular patterns: the generalizability of an inflectional pattern probably depends on the phonological consistency between the verbs sharing the same features. Such a perspective admits the coexistence of multiple levels of rules, varying from an high level of generalizability to an high level of specificity.

If we consider the data by Orsolini and Marslen-Wilson in the light of assumptions of the morpho-pnonological account (Tyler et al., 2005a; Post et al., 2008), according to which the presence of morpho-phonological features acts as cue for the presence of a potential inflectional suffix, determining a *stem+affix* processing of the form, it seems unnecessary to observe that (on the basis of the extreme complexity of Italian verbal morphology, the presence of multiple inflectional classes and the high number of sub-regular families) a decomposed access for inflected forms can be activated by recurrent patterns of morpho-phonological alternation. In this sense, the traditional opposition between decomposed access for regular forms and whole-form recovery for irregular ones appears to be inefficient, since it seems necessary to

consider intermediate cases between regular forms and fully, idiosyncratic irregular forms.

Say and Clahsen (2001) outlined several methodological weaknesses in the experimental design used by Orsolini and Marslen-Wilson (1997): in the first experiment, they mixed roots of the 1st and the 3rd conjugation in the category of regular verbs, assuming that both types of verbs are based on the application of rules, as opposed to the 2nd conjugation irregular verbs. According to Say and Clahsen, only the 1st conjugation has to be considered as the default class, and the priming effect found on regular verbs could have been determined by the presence of verbs that are represented as irregulars; relative to the second experiment, in the category of pseudo-verbs similar to existing roots, only pseudo-verbs of the 2nd and the 3rd conjugation were inserted by Orsolini and Marslen-Wilson. According to Say and Clahsen, if the forms of these verbs are represented as whole-words, they could suffer from a neighbourhood effect.

Say and Clahsen tested the generalizability of the inflectional patterns of the three conjugations of Italian verbs. They conducted an experiment in which subjects had to produce the past participle of novel verbs which were similar or not to regular and irregular verbs of the

2nd and 3rd conjugation. Pseudo-verbs were included in sentence contexts and presented in forms that did not contain the thematic vowel, such as 1st or 2nd singular person or 1st plural person forms of the present tense.

The hypothesis made by Say and Clahsen was that most of the responses had to result in regularizations based on the first conjugation regular pattern, especially in the condition of no similarity; the generalization of 2nd and 3rd conjugation inflectional patterns, on the contrary, had to be conditioned by the similarity to existing roots and their frequency.

Accordingly to the expectations, generalizations of the 1st conjugation regular pattern were the predominant responses in all categories, but particularly on forms with low similarity. A frequency effect was found, with a higher percentage of responses on pseudo-verbs similar to high-frequency verbs, except for the condition of similarity to the 2nd conjugation irregular roots. These results may be due to the higher consistence of the inflectional patterns of low frequency irregular verbs of 2nd conjugation.

As previously assumed by Say and Clahsen, the 1st conjugation pattern was chosen as the default inflection, while the attribution of pseudo-verbs to 2nd

or 3rd conjugation was strongly influenced by phonological neighbourhood and frequency.

However, as pointed out by Eddington (2002), in their experiment Say and Clahsen did not include pseudo-roots similar to verbs of the 1st conjugation in order to verify if they showed the same neighbourhood effect found on 2nd and 3rd conjugation verbs, as observed by Albright (1999).

Walenski, Sosta, Cappa and Ullman (2009), found further support for the hypothesis made by Say and Clahsen (2001) in an experiment of production of inflected forms of real and novel 1st and 2nd conjugation verbs, conducted on a group of Alzheimer patients. The experiment was based on the production of the past participle or the present tense of verbs and pseudo-verbs, given their infinitive. Results were partially compatible with data on English (Miozzo, 2003; Ullman et al., 1997; Ullman et al., 2005): compared with a control group of healthy participants, patients resulted to be impaired in the production of irregular 2nd conjugation verb forms but spared in the production of forms from regular 1st conjugation. Furthermore, they showed an impairment on the production of regular 2nd conjugation present tense forms, and errors on irregular 2nd conjugation verbs did not show a

predominance of regularizations, differently from what had been observed on English. The authors interpreted this more complex pattern of results as reflecting the complexity of the Italian verbal system, but maintained that the results on regular 2nd conjugation forms are coherent with Dual Mechanism, assuming that all verbs of 2nd conjugation are represented as irregular forms.

Further support to a dichotomic dissociation on the processing of Italian verbs comes from neuroanatomical data by Gross, Say, Kleingers, Clahsen and Munte (1998), who used the detection of ERPs during a reading task. Subjects had to read silently a set of words, pushing a button whenever they recognized a noun. The experimental stimuli consisted of three types of pseudo-participles:

- regular 1st conjugation roots inflected according to the regular paradigm of the 3rd conjugation (**parlito* instead of *parlato* (*spoken*));
- regular 3rd conjugation roots where the regular suffix of the 1st conjugation was applied (**dormato* instead of *dormito* (*slept*));
- 2nd conjugation irregular roots inflected according to the regular pattern of the 1st conjugation (**prendato* instead of *preso* (*taken*)).

The experimental pseudo-participles were compared with correct regular or irregular past participles of 1st, 2nd and 3rd conjugation.

Only the regularized pseudo-participles of the 2nd conjugation elicited a widespread negativity (around 250 ms), while, with respect to pseudo-participles of the 3rd and 1st conjugation, it was detected a small difference with responses to correct participles. Despite the fact that these data have been presented as confirming a dissociation between regular and irregular verbs, they do not confirm what hypothesized by Say and Clahsen (2001), who would have predicted that forms such as **parlito* elicit a pattern of response similar to that of regularized 2nd conjugation verbs.

An alternative hypothesis has been taken into account by Orsolini et al. (1998), who conducted an experimental study on the acquisition of past tense in Italian by children. They proposed a revised version of the Dual Mechanism theory, based on the assumption that the processing of forms of the 1st and 3rd conjugation is based on a decompositional mechanism, as demonstrated by the productivity of their inflectional patterns. On the contrary, the 2nd conjugation forms,

which belong to a non-productive class, were assumed to be stored in the mental lexicon.

The first experiment was aimed at testing the production of the past perfect and was based on spontaneous speech of children, who told stories starting from some figures. The most part of errors resulted in over-regularizations of irregular 2nd conjugation verbs through the application of the regular suffix of the same inflectional class; the application by default of the 1st conjugation suffix was very rare and occurred only in responses of younger children. The results of the second experiment by Orsolini et al., which was focused on the production of the past participle, showed a higher level of accuracy but a distribution of errors similar to the previous experiment. Such data are in contrast with the Dual Mechanism theory and better interpretable within a single mechanism perspective.

Such an interpretation has been criticized by Say and Clahsen (2001), who conducted further analyses of the data, pointing out that children produced also a lot of irregularizations of 2nd conjugation irregular verbs similar to other verbs of the same class, while the regularizations of irregular verbs were concentrated almost exclusively on idiosyncratic forms, such as

cadde/**cadè* (*he fell down*), and where attributable to the low frequency of these verbs. In this perspective, the data do not contrast with the Dual Mechanism hypothesis, being consistent with data collected by Marcus (1995) on English, and by Clahsen and Rothweiler (1993) on German.

An alternative interpretation of morphological processing for Italian verbs has also been taken into account by Albright (2002), within the "Islands of Reliability" hypothesis, according to which both regular and irregular forms are processed through the application of multiple phonological rules. Albright conducted an acceptability judgement experiment on novel verbs, aimed at verifying whether subjects choices were influenced by the default mechanism, as expected in a symbolic perspective, or by islands of reliability.

The experiment was based on novel roots, constructed on the basis of the islands of reliability identified by the model of Albright and Hayes (2002). Subjects had to assign an acceptability score, in a scale from 1 to 7, to pseudo-inflected forms of the 1st singular person. Then they were presented with 4 sentences, each containing an infinitive form of the same pseudo-verbs marked by the ending of a specific class (are,-ere, ére,-ire). Finally,

subjects had to judge the acceptability of each alternative.

The results showed that the preferences for all inflectional classes were influenced by the phonological neighbourhood of the pseudo-verbs with existing verbs. Such data are consistent with those reported by Orsolini and Marslen-Wilson (1997) and by Orsolini et al. (1998), but are in contrast with Say and Clahsen's (2001), because they do not confirm a different status of representation of 1st conjugation verbs vs. 2nd and 3rd conjugation verbs. The data by Albright (2002) are generally in conflict with the predictions of the traditional symbolic approach which tends to identify, within each inflectional system, a default class which is activated whenever the access to a stored form fails.

Colombo, Laudanna, De Martino and Brivio (2004) carried out a study on the acquisition of Italian past participle of the 2nd and 3rd conjugation in primary school children, to test their sensitivity to the regularity and the consistency of the mapping between infinite and inflected forms. Children had to produce participle forms of verbs in sentence contexts, starting from the infinitive forms, which were given by the experimenter. According to the Dual Mechanism theory, children should have shown a greater sensitivity to regularity,

making a high number of over-regularizations, independently of the class membership of the verbs. On the contrary, a greater sensitivity to phonological consistency would have been revealed by a predominance of regularizations on the 3rd conjugation verbs, and of sub-regularizations on the2nd conjugation verbs.

The results showed a strong effect of regularity on participial forms from 3rd conjugation, with more accurate responses on regular roots, although the effect tended to decrease in responses given by older children. As to the second conjugation, a greater accuracy was observed on sub-regular verbs, and the effect of regularity disappeared on older children. Furthermore, in most of cases errors made by children consisted of the regularization or sub-regularization of a verb through the application of an inflectional pattern of the same conjugation. Errors of attribution of inflectional class were observed only on younger children. To sum up, the results confirmed the hypothesis of a sensitivity to phonology, and therefore are not interpretable in a Dual Mechanism perspective. The effect of phonological sensitivity also allows to explain the higher level of accuracy on 2nd conjugation sub-regular verbs, which is probably due to the high

phonological consistency of 2nd conjugation sub-regular families. 3rd conjugation regular verbs, on the contrary, have been subject to a regularity effect probably because of the lower consistency of irregular families of this class.

To further investigate the influence of phonological characteristics on the acquisition of verbs, Colombo et al. implemented a three layers feed-forward network, trained to produce the past participle of verbs presented in the infinitive form. The network showed generally more difficult to learn the inflection of verbs of the 3rd conjugation, both regular and irregular, probably because of the length and the morphological complexity of these verbs. The over-regularizations were fewer than to those produced by children, and also the irregularizations of the 2nd conjugation verbs were not comparable to those produced by children, for the most part based on changes in the last part of the root, locus of the attachment of the regular suffix (e.g. *pendere* (*to lean*)/**pensuto* instead of *pensato* (*leant*)). The responses given by the network were predominantly based on a sensitivity to phonological properties, showing that the answers given by children can be reasonably reproduced through a single mechanism model. According to the authors,

differences in the responses by the network with respect to those given by children could be ascribed to the narrowness of the training set administered to the network.

Sonnenstuhl and Huth (2002) have proposed an extension of the symbolic theory, providing the access to a specific class, that is activated when both access to the whole form and decomposed processing fail. Relative to the inflectional classes of Italian, the access to a specific class is determined by the information contained in the thematic vowel. Once the access to a specific class is activated, the root and the suffix are processed separately, and joined together by a concatenative rule. In this perspective, it seems difficult to interpret the higher number of regularizations on the 3rd conjugation verbs than on the 2nd ones found in the experiment by Colombo et al. (2004). Since the experimental stimuli were balanced for frequency, for both classes of verbs the probability that the access failed should be approximately the same, regardless of the prevalence of regular and irregular paradigms within each of them. The results by Colombo et al. therefore seem more congruent with a connectionist approach, which admits the possibility that responses are influenced by both token and type frequency.

Colombo, Fonti and Stracciari (2009) hypothesized that Italian verbs can be placed on a "continuum of regularity", varying from a maximum level of regularity (characterizing 1st conjugation regular verbs), to a maximum level of irregularity (represented by irregular patterns based on the manipulation of the root). "Pseudo-regular" verbs (regular and irregular verbs of 2nd and 3rd conjugation), based on concatenative mechanisms, should be placed halfway of the continuum. The authors tested their hypothesis by studying the production of Italian verbs and pseudo-verbs on a group of Alzheimer patients with damage to the lexical/semantic knowledge. Pseudo-verbs were similar to real regular, pseudo-regular or irregular verbs. Both real and pseudo-verbs were presented in an infinitive condition and in a present tense condition, in which the input did not contain the thematic vowel.

In patients as well as in control group, responses on regular verbs were more accurate than that on pseudo-regulars, which were in turn more accurate than that on irregular verbs, especially in the present tense condition.

The higher number of errors on irregular verbs shows that subjects of both groups had difficulty in manipulating morpho-phonological segments,

especially when the pattern of manipulation was less predictable. However, this difficulty was much more pronounced in patients.

In production of verbs and pseudo-verbs, both groups showed a strong tendency to regularize in absence of information about the conjugation. The data on pseudo-verbs showed that this trend was stronger in the control group. When the input provided information on the conjugation, the same tendency to make pseudo-regularizations was observed in both groups, although the performance of patients was worse in all conditions. The deficit in the access to semantic knowledge influenced the attribution of the inflectional pattern when the input form did not present a clear cue about class membership.

The pattern of errors shown by patients supports the hypothesis of a continuum of regularity suggested by the authors: regular forms were the easiest to produce; pseudo-regular verbs were more difficult, and irregular verbs were the hardest to be produced. In general, inflected forms based on concatenative patterns were simpler than those involving changes in the root. The deficit in the manipulation of morpho-phonological segments could be attributed to an inability to block the interference from phonologically similar verbs, in

agreement with the hypothesis of the attention deficit made by Cortese et al. (2006).

Data by Colombo et al. are only partially compatible with other data on English (Cortese et al. 2006; Ullman et al., 1997): indeed, though patients made more errors on irregular verbs, the choice of an inflectional pattern depended on the modality of presentation of the input, and the 1st conjugation regular pattern was not the only one generalized on pseudo-verbs. This means that regularization errors do not rely necessarily on the application of a rule, but may be based on a strategy that intervenes in absence of further morpho-phonological information;

According to the authors, these data are partially in agreement with the "multiple schemes" model proposed by Bybee (1995), which states that the class membership of a verb is determined by the phonological/semantic relationships with other verbs.

This model explains the different patterns of accuracy associated with the continuum of regularity, but it fails to account for the differences in errors made in the two input conditions, revealing a relationship between the past participle and the first person of the present indicative weaker than the one between past participle and infinitive.

The results obtained on Alzheimer patients have been interpreted as support to the connectionist model proposed by Joanisse and Seidenberg (1999), which maintains that the processing of irregular forms is more influenced by semantic factors. To confirm this interpretation, Colombo et al. (2006), simulated the pattern of accuracy based on the continuum of regularity through a neural network trained to produce the past participle after the presentation of different types of input (infinitive and present tense) .

The generalizability of Italian sub-regular inflectional patterns has been investigated by Laudanna and Gazzellini (2007) in two lexical decision experiments, aimed at testing the role played by morpho-phonological similarity between regular and sub-regular verbs on the recognition of inflected forms. The experiments were based on a visual lexical decision, and a priming paradigm. Stimuli of the first experiment were constructed on the basis of three transformations:

- Pseudo-past participles based on the application of the regular 2nd conjugation past participle suffix on a 2nd conjugation sub-regular verb morpho-phonologically similar to other regular verbs, (e.g., from *tendere* (*to stretch*)/ *teso*

(*stretched*), in analogy with vendere (*to sell*)/*venduto* (*sold*) → **tenduto*);

- Pseudo-past participles formed by roots and suffixes of couples of 2nd conjugation sub-regular verbs morpho-phonologically similar (e.g., from *stringere* (*to tighten*)/*stretto* (*tightened*), in analogy with *fingere* (*to fake*)/*finto* (*faked*) → **strinto*);
- Pseudo- past participles formed by regular 2nd conjugation verbs and suffixes of morpho-phonolgically similar sub-regular 2nd conjugation verbs (e.g. *procedere* (*to proceed*)/*proceduto* (*proceeded*), in analogy with *uccidere* (*to kill*)/*ucciso* (*killed*) → **proceso*).

Each experimental category had a control condition and each item had its own control. According to the Dual Mechanism hypothesis, an inhibitory effect should have been detected on regularized sub-regular roots and sub-regularized sub-regular roots, but not on sub-regularized regular pseudo-participles. The results showed longer reaction times and higher percentages of errors on all the three experimental conditions, demonstrating that the activation of sub-regular and regular patterns is inhibited by the concurrent

activation of the regular or sub-regular inflectional pattern of a morpho-phonologically similar verb.
In the second experiment, aimed at testing whether the inhibitory effect was due to the combination of roots and suffixes of morpho-phonologically similar verbs, the stimuli in the same experimental categories of the previous experiment were formed by the combinations of roots and suffixes of morpho-phonologically not similar verbs:

- Pseudo-past participle forms based on the regular 2nd conjugation past participle suffixation on a 2nd conjugation sub-regular verb not similar to other regular verbs, (e.g., from *rompere* (*to break*)/ *rotto* (*broken*), in analogy with vendere (*to sell*)/*venduto* (*sold*) → **romputo*);
- Pseudo-past participle forms created through roots and suffixes of couples of 2nd conjugation sub-regular verbs not morpho-phonologically similar (e.g., from *correggere* (*to correct*)/*corretto* (*corrected*), in analogy with *prendere* (*to catch*)/*preso* (*caught*) → **correso*);
- Pseudo- past participles shaped on regular 2nd conjugation verbs and suffixes of sub-regular 2nd conjugation verbs not morpho-phonolgically similar

(e.g. *premere* (*to press*)/*premuto* (*pressed*), in analogy with *spegnere* (*to turn off*)/*spento* (*turned off*) → **prento*).

The results of the second experiment confirmed the inhibitory effect only on the category of regularized sub-regular roots, indicating for both regular and sub-regular verbs no sensitivity to implausible sub-regular inflectional patterns. The persistence of the effect on regularized roots can be explained by the higher generalizability of regular inflectional paradigms. The experimental results have been confirmed by Carastro, Cecconi and Laudanna (2007), through a simulation carried out on a connectionist network, trained to produce the past participle or the infinitive form of verbs, given their infinitive or past participle form, respectively. Testing the network on both real verbs and pseudo-past participles used by Laudanna and Gazzellini (2007), it has been observed that the model was able to regularize and sub-regularize new verbs according to the morpho-phonological similarity to existing regular and sub-regular verbs.

As noted by Laudanna (2007), the sensitivity to phonological proximity of regular verbs is not coherent with Dual Mechanism theory, and is compatible with

the predictions of Optimality theory, which states that the generalizability of an inflectional pattern depends on phonological constraints.

2.3 Connectionist models

Eddington (2002) tried to reproduce the results by Say and Clahsen (2001) through a model that uses a single mechanism for the production of inflected forms. The network was based on the AML algorithm (*Analogical Modeling of Language*), a system which is able to simulate how linguistic experiences stored in memory predict linguistic behaviour. Differently from a connectionist network, the AML calculates the probability for an answer to be chosen; in addition, while the network needs a training phase, in AML the information needed to process the items is already stored; finally, the answer provided by a connectionist network is achieved through the activation of different nodes, which often contain partial information about the word to be processed, while AML compares the stimulus provided in input to the forms stored in memory (divided in sub-contexts on the basis of the features that they share with the stimulus to be processed). The items stored in memory that behave differently than members of the same sub-context are excluded.

Eddington provided the model with the 976 most common Italian verbs, making the database as much

representative as possible of the linguistic knowledge of speakers. Then he conducted a simulation based on a task of production of pseudo-verbs, similar to that used by Say and Clahsen (2001). The results of the simulation are only partially comparable with experimental data: pseudo-verbs similar to existing roots showed a high probability of being assigned to the correct conjugation, while the 1st conjugation was chosen as the default category. The frequency effect which had been observed by Say and Clahsen only on irregular roots emerged on all the pseudo-verbs.

Eddington attributed these differences to the fact that responses by human subjects are influenced by many variables, and assumed that it is impossible to fully reproduce the linguistic knowledge of speakers on a computational model. However, as he outlined, the data demonstrate that the role of the default class may be satisfactorily explained by a single mechanism. Eddington hypothesized that the high phonological heterogeneity of the 1st conjugation verbs is sufficient to explain why this class can be considered the default category. Albright and Hayes (2002) confirmed this hypothesis by implementing the Minimal Generalization model on an automated learner program. The result of the simulation was the definition

of a set of phonological environments which describe the morphological patterns if Italian. These phonological environments described rules of various levels of specificity: for instance, 1st conjugation verbs covered a wide and varied morphological space, which carried a minimal level of phonological description.

Calderone (2004) proposed an emergentist perspective on the linguistic learning process, based on the assumption that linguistic phenomena can be seen as the result of the interaction between simple linguistic units. During language acquisition, words are memorized as units of a network, and the morphological relationships between them are consequently expressed by the network connections. Local connections between single nodes influence the global organization of the network, determining the formation of paradigmatic clusters, on the basis of which children are able to make generalizations. This process of "clusterization" is reflected by the spatial localization of units in the network, which can be really seen as a schematization of paradigmatic structures underlying linguistic knowledge.

On the basis of these assumptions, Calderone implemented a particular type of network, defined as SOM (*Self-Organizing Map*), which is able to detect

salient features in the data set during a phase of unsupervised learning, and to develop a self-organized structure. Trained on a corpus of 1560 verbal inflected forms, the network was able to identify a number of categorizations, based on shared of morpho-syntactic features, which reflected specific grammatical categories. Furthermore, the network identified some allomorphs of verbal stems, which were divided into sub-groups.

During the test phase, the network was trained to categorize unfamiliar words, characterized by morpho-syntactic features similar to those previously learned. As expected, the new forms were placed across the map according to the paradigmatic clusters identified during the training phase, reflecting the network's sensitivity to recurrent morpho-syntactic patterns.

Pirrelli, Calderone, Herreros and Virgilio (2004) obtained similar results on a SOM network, tested on a task of categorization of verbal forms. During the training sessions, the network was administered with inflected forms of the same morphological family, and it evolved from an organization of inflected forms around the root, to an organization around suffixes. This evolution, probably comparable to the U-shaped process observed on children, reflects a gradual

increase in the morphological organization of the lexicon, which goes from a form-based representation to an inflectionally based representation.

The network by Pirrelli et al. showed to be sensitive to sub-regularities among verbal paradigms: verbs were grouped in paradigmatic clusters on the basis of morpho-synctactic features, independently from class membership. Furthermore, the spatial extension of clusters was determined by both type and token frequency of members.

On the basis of their simulative data, Pirrelli et al. emphasized the efficacy of associative models, which can be considered, if not an instrument for exhaustive simulation of linguistic phenomena, a tool for an analytical detection of cognitive fields.

Chapter 3 .
Interaction between regular and sub-regular patterns in the recognition of inflected verbal forms

3.1 Introduction

In this chapter I report a set of experiments, which constituted an extension of the experiments on the 2nd conjugation verbs carried out by Laudanna and Gazzellini (2007). In chapter 2, it was outlined that the aim of those experiments was to investigate whether regular and sub-regular inflectional patterns interfere with each other. The goal was accomplished by studying the recognition of pseudo-past participles, constructed by combining stems and inflectional suffixes of morpho-phonologically similar verbs. The authors found an inhibitory effect for lexical decision on both regularized and sub-regularized verbs. Furthermore, the inhibitory effect depended on the morpho-phonological similarity between verbs, since a control experiment, based on pseudo-forms constructed by attaching stems and suffixes of morpho-phonologically inconsistent verbs, did not confirmed

the effect on sub-regularized regular and sub-regular stems.

The Italian second conjugation represents an interesting field of investigation for the interaction between regular and sub-regular patterns, because it is the most irregular inflectional class, and includes a lot of highly phonologically structured sub-regular families. In the experiments that will be presented below, we firstly tried to extend the investigation on the 3rd conjugation (experiments 1 and 2), which is a predominantly regular class and includes a limited number of sub-regular families. Then we turned to study the 1st conjugation (Experiments 3-6). In this case, the limit represented by the absence of sub-regular families was overcome by focusing on the interaction between the regular 1st conjugation pattern and sub-regular 2nd conjugation models. Finally (in Experiment 7), we tried to explore the reciprocal interference between regular, sub-regular and idiosyncratic irregular patterns from all the inflectional classes of Italian. The general goal of our experiments was to clarify whether the traditional dichotomy between regular and irregular verbs, which was observed in studies on English and German, could be replicated on a verbal system based on multiple regular inflectional paradigms and on

irregular patterns with different degrees of phonological consistency and predictability.

3.2 Experiments 1 and 2. Pseudo-past participles of the 3rd conjugation

The goal of the experiments on the 3rd conjugation was to test the likelihood that the inhibitory effect observed on the regularized and sub-regularized roots of the 2nd conjugation is also observed on a productive and predominantly regular inflectional class. This aim was pursued by using as experimental stimuli non-words formed by the combination of stems and inflectional suffixes of morpho-phonologically similar regular and sub-regular verbs.

Only two transformations out of the three employed by Laudanna and Gazzellini were used: sub-regularized regular verbs and regularized sub-regular verbs. Given the limited number of sub-regular roots of the 3rd conjugation, according to the Dual Mechanism theory, only the regularization of sub-regular roots should have interfered with the rejection of the pseudo-words, while the activation of the inflectional rule determined by sub-regularized verbs should have counteracted the influence of morpho-phololological similarity.

On the basis of previous data on processing of verbal forms in Italian (Orsolini and Marslen-Wilson, 1997; Orsolini et al., 1998; Albright and Hayes, 2002), we predicted that the generalizability of sub-regular patterns would have determined an inhibitory effect on both types of transformations, according to the hypothesis that the processing of both sub-regular and regular verbs is influenced by morpho-phonological similarity (Laudanna and Gazzellini, 2007).

3.3 Experiment 1. Lexical decision with priming on 3rd conjugation pseudo-past participles

3.3.1 Method

The experiment was based on a visual lexical decision task with priming. Reaction times and number of errors were the dependent variables.

3.3.2 Participants

The experiment was completed by 40 students from the University of Salerno, native Italian speakers, aged between 19 and 32 years. Each participant took about 25 minutes to complete the experiment.

3.3.3 Stimuli

The experimental list consisted of twenty-four stimuli. twelve of them were pseudo-past participles formed by transforming sub-regular roots according to similar

regular verbs, ending in the infinitive form with the same string of letters (e.g. *riapparire* (*to reappear*)/ *riapparso* (*reappeared*) was transformed according to *trasferire* (*to transfer*)/ *trasferito* (*transferred*), obtaining **riapparito*). Twelve were pseudo-past participles resulted from the transformation of regular 3rd conjugation real roots according to the inflectional pattern of a sub-regular verb of the same class, ending in the infinitive form with the same string of letters (eg. *trasferire/trasferito* was transformed according to *riapparire*/*riapparso*, obtaining **trasferso*). The transformations were orthographically and phonologically plausible, since they were based on the combination of the root with suffixes appropriate for verbs ending (in the infinitive form) with the same pair of syllables.

The experimental verbs involved in the transformations were balanced for frequency and length. The frequency was controlled on the basis of a corpus of almost 4.000.000 occurrences (CoLFIS, *Corpus e lessico di frequenza dell'italiano scritto* (Laudanna, Thornton, Brown, Burani & Marconi, 1995)). We also controlled the number of prefixed verbs within each category.

For each experimental item, a control stimulus was created, in which the penultimate letter was changed in

order to obtain a phonotactically acceptable transformation which was not morphologically salient. For instance, the control stimulus corresponding to **riapparito* was **riapparico*, the control stimulus **trasferso* was **trasferno* (see Appendix A for the complete experimental materials).

Experimental and control stimuli were also balanced for their n-count, i.e. the number of real words obtained by replacing a letter in the pseudo- word (see Table 3.1 for mean values of the parameters controlled in the experimental materials).

stimuli		freq.	lenght	n-count
sub-regularized regulars	exp	351,4	7,41	0,75
	ctrl			0,66
regularized sub-regulars	exp	368,2	8,33	1,33
	ctrl			1,41

Table 3.1. *Mean values for the relevant parameters controlled in Experiment 1.*

In order to avoid any interference effect of morphological structure, we excluded pseudo-words that were decomposable in *word+suffix*, *prefix+suffix* or *word+word*. The whole list of 48 experimental and control stimuli was divided in two sub-lists of 24 items,

included in two different sessions. Members of the same experimental/control pair were always attributed to different sessions. Each participant was administered with only one of the two sessions.

Experimental and control target stimuli (e.g. **riapparito* and **riapparico*) were preceded, in priming position, by the infinitive form of the root involved in the transformation (e.g. *riapparire*).

432 fillers were included in the experiment: 240 words and 192 pseudo-words. They constituted, together with the experimental and control sub-lists, a total of 480 items which formed 240 pairs of primes and targets, divided in the same number of word-word, word-nonword, nonword-word and nonword-nonword pairs.

In order to avoid any interference effect of morphological structure, we excluded pseudo-words that were decomposable in *word+suffix*, *prefix+suffix* or *word+word*. The whole list of 48 experimental and control stimuli was divided in two sub-lists of 24 items, included in two different sessions. Members of the same experimental/control pair were always attributed to different sessions. Each participant was administered with only one of the two sessions.

Experimental and control target stimuli (e.g. **riapparito* and **riapparico*) were preceded, in priming position, by

the infinitive form of the root involved in the transformation (e.g. *riapparire*).

3.3.4 Equipment

The stimuli were displayed on a screen connected to an IBM computer. The experiment run on the E-Prime software.

3.3.5 Procedure

A cross (indicating the point of the screen in which the target stimulus was going to appear) was presented at the centre of a white screen, accompanied by an acoustic stimulus, followed by the prime stimulus and then by the target. The SOA (*Stimulus onset asynchrony*) between prime and target was 250 ms. Participants were given a time limit of 1 second to respond, and their task was to decide, as fast and accurately as possible, if the target word on the screen was or not a real word. The response was given by pressing one of the two buttons at the ends of a keyboard. The response "word" had to be selected with the dominant hand (the responses sides were exchanged for left-handed participants).

The reaction time corresponded to the Interval between the appearance of the target stimulus and the response. The stimuli were divided into 4 blocks of 60 pairs, presented in a random order, as well as the order of the pairs within each block. The experiment was preceded by a training session of 20 pairs.

3.3.6 Results

In table 3.2 I report the mean reaction times and the percentages of errors of Experiment 1. A two-way analysis of variance was conducted. The two factors were type of transformation (regularized sub-regulars vs. sub-regularized regulars) and condition (experimental vs. control).

stimuli		RT (ms)	errors (%)
sub-regularized regulars	exp	701	14,2
	ctrl	664	4,2
regularized sub-regulars	exp	744	42,9
	ctrl	683	11,7

Table 3.2. *Mean reaction times and percentage of errors in Experiment 1.*

The ANOVA on reaction times showed a significant effect of transformation in both the analysis by participants ($F(1.19) = 19.59$, $p<.005$) and in the one by items ($F(1.44) = 4.70$, $p<.05$). The effect of condition was significant in the analyses by participants ($F(1.19) = 83.86$, $p<.001$) and by items ($F(1.44) = 12.25$, $p<.001$). The interaction between condition and transformation was significant in the analysis by participants ($F(1.19) = 6.31$, $p<.025$), not in the analysis by items ($F(1.44) = 1.05$, $p > .3$).

The effect of transformation on errors was significant, both in the analyses by participants ($F(1.19) = 55.94$, $p<.001$), and in the one by items ($F(1.44) = 28.8$, $p<.001$). The effect of condition was significant in the analyses by participants ($F(1.19) = 96.04$, $p<.001$) and by items ($F(1.44) = 37.29$, $p<.001$). The interaction between condition and transformation was significant, both by participants, ($F(1.19) = 13.1$, $p<.001$) and by items ($F(1.44) = 9.9$, $p<.005$).

LSD post-hoc analyses based on the comparisons between each experimental category and its corresponding control category, revealed significant differences on reaction times between regularized ($p<.05$) as well as sub-regularized pseudo-verbs ($p<.001$) and their respective controls. Significant differences were also found on errors in categories of regularized ($p<.001$), and sub-regularized roots ($p<.05$).

Summing up, the results revealed longer reaction times and higher error rates on both the experimental categories as compared to their controls. The interaction between condition and transformation on reaction times and errors showed that the difference between experimental and control pseudo-participles was stronger for sub-regularized verbs. Such a difference can be explained by the fact that, while

regularized forms may be decomposed into morphological constituents (*root+suffix*), sub-regularized forms are only partially decomposable. This explanation converges with the one offered for the results of other experiments on morphological pseudo-words (Caramazza et al., 1988).

These data demonstrate that the 3rd conjugation regular verbs are sensitive to their similarity to morpho-phonological sub-regular verbs. However, the regular paradigm was observed to be more robust and less sensitive to inhibitory effects than the sub-regular patterns, probably because of the higher phonological heterogeneity of regular 3rd conjugation verbs.

3.4 Experiment 2. Simple lexical decision on 3rd conjugation pseudo-past participles

The second experiment was aimed at determining whether the inhibitory effect observed in the first priming experiment was due to the presentation of the prime (which presumably pre-activated the verbal root), or whether the same pattern of results emerges when pseudo-participles are presented in isolation.

3.4.1 Method

The second experiment was based on a simple lexical decision task. The reaction times and the number of errors were the dependent variables.

3.4.2 Participants

The experiment was completed by 40 students from the University of Salerno, native Italian speakers, aged between 19 and 36 years. Each participant took approximately 20 minutes to complete the experiment.

3.4.3 Stimuli

The same experimental target stimuli as the previous experiment were used.

3.4.4 Equipment

The stimuli were displayed on a screen connected to an IBM computer. The experiment run on the E-Prime

3.4.5 Procedure

A cross (indicating the point of the screen in which the target stimulus was going to appear) was presented at the centre of a white screen, accompanied by an acoustic stimulus, and followed by the target stimulus. Participants were given a time limit of 1 second to respond, and their task was to decide, as fast and accurately as possible, if the target word on the screen was or not a real word. The response was given by

pressing one of the two buttons at the ends of a keyboard. The response "word" had to be selected with the dominant hand (the responses corresponding to the two buttons were inverted for left-handed participants).

The reaction times corresponded to the interval between the appearance of the target stimulus and the response. The stimuli were divided into 4 blocks of 60 pairs, presented in a random order, as well as the order of the pairs within each block. The experiment was preceded by a training session of 20 stimuli.

3.4.6 Results

In table 3.3 the mean reaction times and the percentages of errors of Experiment 2 are reported. The analysis showed a main effect of condition, with longer response times and higher error rates on both experimental conditions than on their controls.

stimuli		RT (ms)	errors (%)
sub-regularized regulars	exp	715	27,2
	ctrl	670	14,6
regularized sub-regulars	exp	742	47,6
	ctrl	703	15,7

Table 3.3. *Mean reaction times and percentage of errors in Experiment 2*

The ANOVAs on reaction times showed significant effects of transformation by participants ($F(1.19) = 17.95$, $p<.001$) and by items ($F(1.44) = 4.27$, $p<.05$). A significant effect of condition was also observed, both by participants ($F(1.19) = 20.49$, $p<.001$) and by items ($F(1.44) = 7.96$, $p<.01$). The interaction between condition and transformation is not significant in analyses by participants and by items.

In the analyses on errors, the effect of transformation was significant by participants ($F(1.19) = 22.64$, $p<.001$), as well as by items ($F(1.44) = 8.31$, $p<.005$). The effect of condition was significant, both in the analysis by participants ($F(1.19) = 146.86$, $p<.001$), and in the one by items ($F(1.44) = 28.65$, $p<.001$). The interaction between condition and transformation was significant in the analysis by participants ($F(1.39) = 6.4$, $p<.01$), but not significant in the one by items ($F(1.44) = 2.28$, $p>.1$).

The LSD post-hoc comparisons on reaction times showed significant differences between both the category of regularized sub-regulars ($p<.05$), and sub-regularized regulars ($p<.005$), and their respective controls. The comparisons on errors also showed significant differences on regularized sub-regulars ($p<.001$) and on sub-regularized regulars ($p<.001$) as compared to their controls.

Even in Experiment 2, the exposure to pseudo-words based on roots and suffixes of morpho-phonologically similar verbs determined an inhibition on both regular and sub-regular verbs. Similarly to what we observed in the previous experiment, the difference between experimental and control stimuli was larger in the category of regularized sub-regular verbs.

The inhibitory effect on the experimental categories in both priming and simple lexical decision experiments suggests that the effect itself cannot be solely interpreted on the basis of the pre-activation of the verbal root by means of the prime. The results of Experiments 1 and 2 confirm those previously obtained by Laudanna and Gazzellini (2007) on the 2nd conjugation, demonstrating that the morpho-phonological similarity determines a reciprocal interference between regular and sub-regular patterns, even in an inflectional class (the 3rd conjugation) based on a robust regular inflectional paradigm.

3.5 Experiments 3 and 4. Pseudo-past participles of the 1st conjugation

The experiments on the 1st conjugation represent a focal point in the development of this study. 1st conjugation is usually excluded by the experimental

studies on the processing of Italian verbs, probably because it is an almost completely regular (and productive) class. Say and Clahsen (2001) argued that the regular inflectional paradigm of the 1st conjugation can be considered the default model, and that it is insensitive to effects of frequency and phonological similarity. Our aim was to challenge this assumption, by hypothesizing that the activation of the 1st conjugation regular pattern is actually inhibited by the competitive activation of a sub-regular pattern. In the following two paragraphs, two lexical decision experiments will be presented. They are modelled on the basis of the experiments on pseudo-past participles of the 2nd conjugation (Laudanna and Gazzellini, 2007), and on pseudo-past participles of the 3rd conjugation, (paragraphs 3.3 and 3.4 of this thesis). In the experiments on the 1st conjugation we created pseudo-past participles resulting from the sub-regularization of regular 1st conjugation roots, according to the sub-regular inflectional patterns of morpho-phonologically similar verbs of the 2nd conjugation. Our expectation was to find an inhibitory effect on the recognition of experimental pseudo-forms, due to the application of a minor inflectional pattern of sub-regular verbs which

are morpho-phonologically similar, although belonging to a different inflectional class.

3.6 Experiment 3. Lexical decision with priming on 1st conjugation pseudo-past participles

3.6.1 Method

The experiment was based on a visual lexical decision task with priming. Reaction times and number of errors were the dependent variables.

3.6.2 Participants

46 students from the University of Salerno completed the experiment, all native Italian speakers, aged between 19 and 37 years. Each of them took approximately 20 minutes to complete the experiment.

3.6.3 Stimuli

The experimental list was composed of 20 pseudo-past participles of real 1st conjugation regular verbs. The transformations were orthographically and phonologically plausible, and resulted in combinations of roots with inflectional suffixes of morpho-phonologically similar verbs. More specifically, they represented sub-regularizations of regular 1st conjugation verbs, through an inflectional suffix of a morpho-phonologically similar 2nd conjugation sub-regular verb (e.g. *regalare* (*to donate*)/*regalato* (*donated*)

was transformed in analogy with *valere* (*to be worth*)/*valso* (*been worth*), and the result was **regalso*). For each experimental item, a control stimulus was also created, in which the penultimate letter was substituted in order to obtain a phonotactically acceptable transformation which was not morphologically salient. For example, the control stimulus corresponding to **regalso* was **regaldo* (see Appendix B for the complete experimental materials).

Experimental and control stimuli were balanced according to the n-count and the number of real words embedded within stimuli.

Furthermore, we controlled the frequency of the final trigrams of the experimental and control pseudo-forms (see Table 3.4 for mean values of the parameters controlled in the experimental materials).

stimuli	experimental items	control items
n-count	1,1	1,2
embedded words	0,8	0,7
final trigrams logarithmic frequency	8,4	7,4

Table 3.4. *Mean values for the relevant parameters controlled in Experiment 3.*

In order to avoid any interference effect of morphologcical structure, we excluded pseudo-words that were decomposable in *word+suffix*, *prefix+root* or *word+word*. The whole list of 40 experimental and control stimuli was divided in two sub-lists of 20 items, included in two sessions. Experimental and corresponding control stimuli were always included in different sessions. Each participant was administered with only one of the two sessions. Experimental and control stimuli were preceded, in priming position, by the infinitive form of the 1st conjugation root involved in the transformation.

360 fillers were included in the experiment, 200 of them were words and 160 pseudo-words. Together with the experimental and control sub-lists, they made up a total of 400 items (200 primes-targets pairs, with the same number of word-word, word-nonword, nonword-word and nonword-nonword pairs).

In order to avoid strategic effects due to the recurrent presentation of pairs of real infinitive forms and pseudo-past participles, we included, among the filler word-word pairs, a group of 10 pairs of real 1st conjugation infinitives and past participles forms, balanced in frequency and length with those used in the experimental list.

3.6.4 Equipment

The stimuli were displayed on a screen connected to an IBM computer. The experiment run on the E-Prime software.

3.6.5 Procedure

We used the same procedure as in experiment 1. The stimuli were divided into 4 blocks of 50 pairs, presented in a random order, as well as the order of the pairs within each block. The experiment was preceded by a training session of twenty pairs.

3.6.6 Results

In table 3.5 I report the mean reaction times and the percentages of errors of Experiment 3. The experimental condition displayed longer reaction times and higher error rates than the control condition.

stimuli	experimental items	control items	difference
RT (ms)	647	634	13
errors (%)	10	3,7	6,3

Table 3.5. *Mean reaction times and percentage of errors in Experiment 3.*

The ANOVA on reaction times showed a significant effect of condition in the analysis by participants ($F(1.22) = 4.80$, $p<.04$), but not in that by item ($F(1.38) = 1.61$, $p>.2$). In the analyses on errors, the effect was significant both by participants ($F(1.22) = 16.61$, $p<.005$), and by items ($F(1.38) = 5.84$, $p < .01$).

The results on the 1st conjugation sub-regularized verbal forms are different from those predicted by Say & Clahsen (2001), since they seem to indicate that the processing of regular 1st conjugation verbs is influenced by the morpho-phonological similarity, in the same way as 2nd and 3rd conjugation forms.

3.7 Experiment 4 - simple lexical decision on 1st conjugation pseudo-past participles

3.7.1 Method

The fourth experiment was based on a simple lexical decision task. The reaction times and the number of errors were the independent variables.

3.7.2 Participants

The experiment was completed by 40 students from the University of Salerno, native Italian speakers, aged between 19 and 34 years. Each participant took approximately 15 minutes to complete the experiment.

3.7.3 Stimuli

The experimental target stimuli were the same as in Experiment 3.

3.7.4 Equipment

The stimuli were displayed on a screen connected to an IBM computer. The experiment run on the E-Prime software.

3.7.5 Procedure

The same procedure as in Experiment 2 was used. The stimuli were divided into 4 blocks of 50 pairs, presented in a random order, as well as the order of the pairs within each block. The experiment was preceded by a training session of 20 stimuli.

3.7.6 Results

Two pairs of items (**afferso*/**afferno* and **scivolso*/**scivoldo*) were eliminated by the analysis, because they reported an error rate too higher as compared to the average of the other stimuli. Response times were slower on experimental items than on control stimuli.

In table 3.6 the mean reaction times and the percentages of errors of Experiment 4 are reported.

stimuli	Experimental items	Control items	Difference
RT (ms)	670	655	15
Errors (%)	11	9	2,00

Table 3.6. *Mean reaction times and percentage of errors in Experiment 4.*

The ANOVAs on reaction times showed a significant effect of condition in the analysis by participants ($F(1.19) = 10.52$, $p<.005$), but not in that by item ($F(1.32) = .94$, $p>.33$). The analyses on errors revealed no effect both by participants, and by items.

The simple lexical decision experiment had to clarify whether and to what extent the inhibitory effect observed in the priming experiment depended exclusively on the information on the verbal root pre-activated by the prime.

Although the inhibitory effect on the simple lexical decision task resulted to be weaker than that observed in the previous experiment, it is nonetheless significant, and still shows an interference on the rejection of

pseudo-participles, probably due to the use of morpho-phonologically consistent sub-regular patterns.

3.8 Experiments 5 and 6. Pseudo-inflected forms of the 1st conjugation

In Experiments 1-4, we evaluated the processing of regularized and sub-regularized pseudo-past participles. It was found that regular and sub-regular inflectional patterns of morpho-phonologically similar verbs interfere with each other in the rejection of the pseudo-participles. The choice of past-participle was motivated by the fact that several sub-regular patterns of Italian involve the past participle. In Experiments 5 and 6 we extended our investigation to sub-regular patterns of the present and future indicative. Our aim was to verify if the sub-regular patterns of the present and future indicative of the 2nd conjugation verbs were robust enough to interfere with the activation of the regular 1st conjugation pattern. The greater complexity of the Italian verbal system, as compared to languages as English, allows us to investigate more deeply the differences in the processing of regular and irregular (or sub-regular) verbs.

In these experiments we used sub-regularized pseudo-forms of the 1st conjugation regular verbs. We expected

to observe a delay in processing these pseudo-forms as non-words, which incorporated inflectional patterns of morpho-phonologically similar sub-regular verbs.

3.9 Experiment 5. Lexical decision with priming on pseudo-inflected forms of the 1st conjugation

3.9.1 Method

The experiment was based on a visual lexical decision task with priming. Reaction times and number of errors were the dependent variables.

3.9.2 Participants

40 students from the University of Salerno completed the experiment, all native Italian speakers, aged between 19 and 30 years. Each of them took approximately 20 minutes to complete the experiment.

3.9.3 Stimuli

The experimental list was composed of 20 pseudo-inflected forms of the present or future indicative of real 1st conjugation regular verbs. The transformations were orthographically and phonologically plausible because they resulted in combinations of roots with inflectional suffixes of morpho-phonologically similar verbs. More specifically, they represented sub-regularizations of regular 1st conjugation verbs, through an inflectional suffix of a morpho-phonologically similar

2nd conjugation sub-regular verb (e.g. *cucinare* (*to cook*)/*cucino* (*I cook*) was transformed in analogy with *tenere* (*to hold*)/*tengo* (*I hold*), and the result was **cucingo*).

For each experimental item, a control stimulus was also created, in which a letter or a couple of letter in the last string of letters of the pseudo-form were substituted, in order to obtain a phonotactically acceptable transformation which was not morphologically salient. For example, the control stimulus corresponding to **cucingo* was **cucinzo* (see Appendix C for the complete experimental materials).

Experimental and control stimuli were balanced according to the n-count and the number of real words embedded within stimuli (see Table 3.7 for mean values of the parameters controlled in the experimental materials).

stimuli	experimental items	control items
n-count	0,5	0,7
embedded words	0,9	0,8

Table 3.7. *Mean values for the relevant parameters controlled in Experiment 5.*

In order to avoid any interference effect of morphological structure, we excluded pseudo-words

that were decomposable in *word+suffix*, *prefix+root* or *word+word*. The whole list of 40 experimental and control stimuli was divided in two sub-lists of 20 items, included in two sessions. Experimental and corresponding control stimuli were always included in different sessions. Each participant was administered with only one of the two sessions.

Experimental and control stimuli were preceded, in priming position, by the infinitive form of the 1st conjugation root involved in the transformation.

360 fillers were included in the experiment, 200 of them were words and 160 pseudo-words. Together with the experimental and control sub-lists, they made up a total of 400 items (200 prime- target pairs, with the same number of word-word, word-nonword, nonword-word and nonword-nonword pairs).

Among the filler word-word pairs, we included a group of 10 pairs of real 1st conjugation infinitives and inflected forms of present and future indicative, balanced in frequency and length with those used in the experimental list.

3.9.4 Equipment

The stimuli were displayed on a screen connected to an IBM computer. The experiment run on the E-Prime software.

3.9.5 Procedure

The same procedure of experiment 1 and 3 was used. The stimuli were divided into 4 blocks of 50 pairs, presented in a random order, as well as the order of the pairs within each block. The experiment was preceded by a training session of 20 prime/target pairs.

3.9.6 Results

Two couples of experimental and control stimuli (**rovirrebbe*/**rovippebbe* and **elimirrei*/**eliminnei*), which presented an high number of errors, were excluded by the analyses.

stimuli	experimental items	control items	difference
RT (ms)	686	660	26
errors (%)	15	6	9,00

Table 3.8. *Mean reaction times and percentage of errors in Experiment 5.*

In table 3.8 I report the mean reaction times and the percentages of errors of Experiment 5. The analysis

shows longer reaction times and a higher error rate in the experimental condition as compared to the control condition.

The ANOVAs on reaction times showed a significant effect of condition in the analysis by participants ($F(1.19) = 13.5$, $p < .001$), but not in that by items. In the analyses on errors, the effect was significant both by participants ($F(1.19) = 15.7$, $p < .001$), and by items ($F(1.34) = 5.3$, $p < .05$).

The results on sub-regularized pseudo-forms of the 1st conjugation are similar to those of Experiments 3 and 4 on the pseudo-past-participle forms. Therefore, a further simple lexical decision experiment was conducted, to ascertain whether the inhibitory effect is still effective when sub-regularized pseudo-forms are presented in isolation.

3.10 Experiment 6. Simple lexical decision on pseudo-inflected forms of the 1st conjugation

3.10.1 Method

In Experiment 6 we used a simple lexical decision task. The reaction times and the number of errors were the independent variables.

3.10.2 Participants

The experiment was completed by 40 students from the University of Salerno, native Italian speakers, aged between 19 and 29 years. Each participant took approximately 15 minutes to complete the experiment.

3.10.3 Stimuli

The same experimental target stimuli as in the previous experiment were used.

3.10.4 Equipment

The stimuli were displayed on a screen connected to an IBM computer. The experiment run on the E-Prime software.

3.10.5 Procedure

We used the same procedure as in Experiments 2 and 4. The stimuli were divided into 4 blocks of 50 pairs, presented in a random order, as well as the order of the pairs within each block. The experiment was preceded by a training session of 20 stimuli.

3.10.6 Results

Two items (**rovirrebbe*/**rovippebbe*) were eliminated by the analysis, because of their too higher error rate as compared to the average of the other stimuli. In table 3.9 the mean reaction times and the percentages of errors of Experiment 6 are reported. The analysis

showed longer response times on experimental items than on control items.

stimuli	experimental items	control items	difference
RT (ms)	709	691	18
errors (%)	18	10	8,00

Table 3.9. *Mean reaction times and percentage of errors in Experiment 6.*

The ANOVAs on reaction times showed a significant effect of condition in the analysis by participants ($F(1.19) = 9.3$, $p < .05$), but not by items ($F(1.36) = .9$, $p > .3$).

The analyses on errors revealed a significant effect of condition in the analysis by participants ($F(1.19) = 11.9$ $p < .005$), but no effects in the analysis by items.

The results of Experiment 6 confirm those obtained on pseudo-inflected forms of the 1st conjugation in the experiment with priming. they allow us to observe that the inhibitory effect is due to the interference of morpho-phonologically consistent sub-regular patterns.

3.11 Further analyses on Experiments 3-6 (1st conjugation)

Some criticisms might be levelled against the previously described experimental data. For instance, processing of pseudo-forms may have been influenced by uncontrolled factors, such as the fact that a root fragment, combined with a pseudo-suffix, may activate not only the root of the target verb, but also any other cohort word sharing the same initial fragment. In particular, such a possibility seems to be plausible for experiments of simple lexical decision, in which the pseudo-forms were presented in isolation, and the root of the target verb was not pre-activated by the prime. This hypothesis would nonetheless be insufficient to explain why we found differences between experimental and control pseudo-forms: they always shared the same initial fragments. However, we controlled "a posteriori" the likelihood that the effects of morpho-phonological similarity were attributable to the virtual presence of orthographic competitors. The experimental list of the 3rd conjugation pseudo-past participles was excluded by these further analyses, because it contained stimuli with a very small number of competitors.

We conducted an ANOVA on the Experiment 4 (simple lexical decision) on pseudo-participles, after having divided the experimental list into two sub-lists of experimental and control pairs containing initial segments with or without competitors. We obtained a sub-list of 9 items without competitors, and a sub-list of 11 stimuli with competitors. The sub-lists were submitted separately to the analysis of variance.

Among pseudo-forms without competitors, we found a significant effect of condition on reaction times by participants ($F(1.19) = 17.7$, $p<.001$), and a quasi-significant effect on items ($F(1.18) = 3.6$, $p<.07$). On errors, no significant difference were observed. Pseudo-forms with competitors revealed no significant effects. The results of the analyses on items without competitors confirmed the inhibitory effect on reaction times found on the whole experimental list, in spite of the reduced number of items.

As to Experiment 6 on the 1st conjugation sub-regularized pseudo-inflected forms, we obtained a sub-list of 13 pairs with competitors, and a sub-list of only 6 pairs without competitors. For this reason, we conducted a simple regression to test the reliability of the number of competitors as a predictor of reaction times and errors. The regression on the whole list of

experimental and control items did not reveal any significant effect either on reaction times (R=-0.17, F(1.36) = 1.1), or on errors (R= -0.18, F(1.36) = 1.16). The same result emerged by the regression on the experimental list, both on reaction times (R=0.15, F(1.17) =0.42), and on errors (R=.05, F(1.17) =.04). The regression on control list revealed negative correlation between number of competitors and reaction times (R=-0.48, F(1.17) = 5.23, p<.05), and a quasi-significant effect on errors (R=-0.41, F(1.17) = 3.6, p<.07). This result suggests that the lower the number of competitors, the higher reaction times and rate of errors. On the basis of our preliminary hypotheses, such a result is hard to explain if we consider that control pseudo-forms are not morphologically analyzable. Thus, a putative inhibition on their processing would be interpretable only on the basis of the interference by multiple competitors. Furthermore, this result was not confirmed by regressions on the whole list and on the experimental list.

3.12 Experiment 7: a comparison between regular, irregular and sub-regular verbal pseudo-forms

On the basis of the data described up to now, we may conclude that sub-regular inflectional patterns are

halfway between regular and fully irregular models, since, although not regular, they are shared by morpho-phonologically well-structured verbal families. In this perspective, we imagine that the attractiveness of an inflectional pattern is determined by its phonological predictability and by number and frequency of verbs which share the pattern itself.

In experiment 7, we studied regular, sub-regular and irregular verbs of all Italian conjugations, in a lexical decision task with priming paradigm. The aim of the experiment was to obtain a measure of the reciprocal interference between regular, sub-regular and irregular verbs of different inflectional classes, through a direct comparison. We compared pseudo-forms obtained by the regularization of irregular or sub-regular verbs, or by the sub-regularization of regular verbs. In accordance with the "Word and Paradigms" theory (Matthews, 1974; Aronoff, 1994; Beard, 1995; Blevins, 2003), and the "Multiple Correspondence" hypothesis put forward by Burzio (1998), we predicted that the processing of pseudo-forms is affected by the strength of different types of inflectional patterns. A higher level of inhibition should be found on the regularized irregular verbs; a lower one should be detected on sub-regularized regular verbs.

3.12.1 Method

The experiment was based on a visual lexical decision task with priming. Reaction times and number of errors were the dependent variables.

3.12.2 Participants

40 students from the University of Salerno completed the task, all native Italian speakers, aged between 19 and 33 years. Each participant took about 25 minutes to complete the experiment.

3.12.3 Stimuli

The whole experimental list was made up of three sub-lists of 14 past participle or present indicative pseudo-inflected forms. They were obtained by applying three types of transformations on real 1st , 2nd and 3rd conjugation verbs:

- regularization of an irregular root of the 1st or 2nd conjugation, through the application of the regular inflectional rule of its inflectional class (e.g. **muovere* (*to move*)/*mossa* (*moved*), was regularized according to the regular inflectional pattern of 2nd conjugation, and the result was **muovuta*);
- regularization of a sub-regular root of the 2nd or 3rd conjugation, through the application of the regular inflectional rule of its inflectional class

(e.g. **salire* (*to go up*)/*salgo* (*I go up*), was regularized according to one of the regular inflectional patterns of 3rd conjugation, and the result was **salisco*);

- Sub-regularization of a regular root of the 1st, 2nd or 3rd conjugation, through the application of the inflectional pattern of a morpho-phonologically similar sub-regular verb (e.g. **rivelare* (*to reveal*)/*rivelo* (*I reveal*), was transformed in analogy to *salire/salgo*, and the result was **rivelgo*).

Each experimental pseudo-form was preceded, in prime position, by a regular form of the original verb. In order to exclude any effect arising from differences in the orthographic overlap between prime and target among the three experimental categories, we created three distinct control categories, where the same transformations on experimental roots were applied on orthographically similar non verbal roots (the control stimuli for **muovuta*, **salisco* and **rivelgo* were, respectively: **rovuta* from *rovo* (*bramble*), **quesisco* from *quesito* (*question*), **candelgo* from *candela* (*candle*)). Control stimuli were preceded by the correct form of the base word (see Appendix D for the

complete experimental materials). The average orthographic overlap between prime and target was kept balanced between experimental categories and their controls. The experimental regular, sub-regular and irregular lists were balanced for the median of their root frequency and for frequency of the real inflected forms involved in the transformation, (on the basis of a corpus of almost 4.000.000 occurrences, CoLFIS, *Corpus e lessico di frequenza dell'italiano scritto*, Laudanna et al., 1995). The number of pre-fixed verbs and the number of pseudo-forms from past participle vs. indicative present was also controlled. Experimental and control lists were balanced for average form frequency, length and n-count, and for the number of real words embedded in the pseudo-forms. (see Table 3.10 for mean values of the parameters controlled in the experimental materials).

The whole list of 84 experimental and control pairs was divided in two sub-lists of 42 pairs, included in two sessions. Members of the same experimental/control pair were always attributed to different sessions. Each participant was administered with only one of the two sessions.

596 fillers were included in the experiment: 298 words and 298 pseudo-words. Together with the experimental

and control sub-lists, they made up a total of 780 items (240 pairs of primes and targets, with the same number of word-word, word-nonword, nonword-word and nonword-nonword pairs).

imuli	category	root frequency (median)	form frequency	lenght	n-count	embedded words	prefixed verbs	ortog overlap
larized gulars	exp	190,5	25,8	7,14	1,14	9	5	0,61
	ctrl		29,6	7,14	1	9		0,6
larized ub-gulars	exp	194,5	28,9	7,14	1,07	10	5	0,71
	ctrl		30,3	7,14	1,07	9		0,72
ub-larized gulars	exp	175	25,2	7,14	1,07	10	6	0,65
	ctrl		25	7,07	1,07	10		0,63

Table 3.10. *Mean values for the relevant parameters controlled in Experiment 7.*

In order to avoid strategic effects due to the recurrent presentation of pairs of real infinitive forms and pseudo-forms, or of real words and orthographically similar non-words, we included as filler pairs a group of 21 pairs of real inflected forms of 1st, 2nd and 3rd

conjugation, and 21 pairs of orthographically similar nouns or adjectives.

3.12.4 Equipment

The stimuli were displayed on a screen connected to an IBM computer. The experiment run on the E-Prime software.

3.12.5 Procedure

The same procedure as in Experiments 1, 3 and 5 was used. The stimuli were divided into 5 blocks of 68 pairs, presented in a random order, as well as the order of the pairs within each block. The experiment was preceded by a training session of 20 pairs.

3.12.6 Results

In table 3.11 I report the mean reaction times and the percentages of errors of Experiment 7. The analyses showed longer reaction times and higher error rates on all the three experimental categories as compared to their respective control categories. Among the experimental items, regularized irregular and sub-regular pseudo-forms gave rise to more errors than sub-regularized regular pseudo-forms.

The ANOVAs on reaction times showed an effect of type of transformation (regularized irregulars, regularized sub-regulars and sub-regularized regulars), which was significant by participants ($F(2.38) = 6.95$,

p<.001), and marginally significant by items (F(2.78) = 2.82, p<.07); the effect of condition (control vs. experimental) was significant both by participants (F(1.19) = 34.3, p<.001), and by items (F(1.78) = 15.62, p<.001); the interaction between type and condition was significant by participants (F(2.38) = 5.84, p<.005), but not by items (F(2.78) = .81, p >.4);

stimuli	category	errors (%)	RT (ms)
regularized irregulars	exp	29,6	708
	ctrl	8,6	682
regularized sub-regulars	exp	25	698
	ctrl	10	682
sub-regularized regulars	exp	16,1	704
	ctrl	7,2	646

Table 3.11. *Mean reaction times and percentage of errors in Experiment 7.*

LSD Post hoc comparisons showed shorter reaction times on sub-regularized regulars with respect to regularized irregulars (p<.005 by participants, p<.05 by items) and regularized sub-regulars (p<.005 by participants, p<.05 by items); furthermore, we observed significantly higher reaction times on experimental sub-regularized regulars than on their control category

(p<.001 by participants, p<.001 by items) and on experimental regularized irregulars as compared to their controls (p<.005 by participants, p<.06 by items, marginally significant); the difference between experimental regularized sub-regulars and their controls was marginally significant by participants (p<.08). No differences were observed between the three experimental categories.

The ANOVA on errors showed a significant difference between type of transformation only by participants ($F(2.38) = 13.71$, $p<.001$); (items: $F(2.78) = 2.43$, $p<.09$). The effect of condition was significant both by participants ($F(1.19) = 66.67$, $p<.001$), and by items ($F(1.78) = 26.34$, $p<.001$); the interaction between type and condition was significant by participants ($F(2.38) = 3.78$, $p<.05$), but not by items.

LSD Post hoc comparisons showed lower error rates on sub-regularized regulars than on regularized irregulars (p<.001 by participants, p<.05 by items) and regularized sub-regulars (p<.001 by participants). Significantly higher error rates were observed on each experimental category and its own control category: sub-regularized regulars (p<.005 by participants, p<.08 by items, marginally significant); regularized irregulars (p<.001 by participants, p<.001 by items); regularized sub-regulars

with respect to their controls ($p<.001$ by participants, $p<.005$ by items).

The results of Experiment 7 are only partially consistent with our expectations. The effect of morpho-phonological similarity, already found in previous experiments, was confirmed by means of a direct matching between regular, sub-regular and irregular verbs; furthermore, the inhibition on regular verbs resulted to be lower than the one observed on sub-regular and irregular verbs, in accordance with results from Experiments 1 and 2 on 3rd conjugation verbs. However, we did not find a difference in the magnitude of the inhibitory effect between sub-regular and irregular verbs. It is worth observing that our results are unavoidably incomplete, because it was not possible to create an experimental category of irregularized regular roots. Many idiosyncratic irregular patterns, indeed, are based on the substitution of the verbal root with a completely different irregular root. Such an unpredictable transformation cannot be generalized to other roots, so it was impossible to test the attractiveness of irregular patterns on regular verbs. It remains that regular inflectional patterns are characterized by a higher attractiveness on sub-regular

verbs, as demonstrated by the stronger inhibitory effect on regularized pseudo-forms.

3.13 Experiments 1-7: general discussion

In all the experiments on the processing of verbal pseudo-forms from regular and sub-regular verbs of all the three conjugations of Italian, we observed that the morpho-phonological similarity influences the processing of regular as well as sub-regular and irregular verbs. The magnitude of the effect varies along the different classes under consideration. Regular verbs from the 1st conjugation are less sensitive to morpho-phonological similarity than verbs from the other two conjugations, and regular 3rd conjugation verbs seem to be less sensitive than sub-regular verbs from the same conjugation.

Far from having replied the results by Say and Clahsen (2001) about the status of the 1st conjugation as the default class, we reconsidered the traditional opposition, made by Dual Mechanism models, between regular and irregular verbs. We assumed that the strength of an inflectional pattern can be evaluated on the basis of a criterion of attractiveness, which defines the likelihood that an inflectional model is generalized

to other verbal roots or pseudo-roots. This attractiveness could depend on the numerosity, frequency and morpho-phonological variability of verbs sharing the same inflectional pattern. On the basis of this criterion, it is possible to broadly define three different levels of strength of inflectional patterns:

1. maximum attractiveness, typical of regular verbs without sub-regular competitors (e.g., some 3rd conjugation verbs (*dormire* (*to sleep*)/*dormito* (*slept*)), or verbs belonging to a predominantly regular inflectional class (e.g., regular 1st conjugation verbs);
2. medium attractiveness, characteristic of:
    - regular verbs with competitors (e.g. *premere* (*to press*)/*premuto* (*pressed*) which have sub-regular competitors such as *presumere* (*to pretend*)/*presunto* (*pretended*)),
    - sub-regular verbs with few regular or sub-regular competitors, or belonging to sub-regular families including many high frequency verbs (e.g. *spingere* (*to push*)/*spinto* (*pushed*), *fingere* (*to feign*)/*finto*

(*feigned*); *aprire* (*to open*)/ *aperto* (*opened*), *coprire* (*to cover*)/*coperto* (*covered*));

3. minimum attractiveness, peculiar of fully idiosyncratic irregular verbs (*cuocere* (*to cook*)/*cotto* (*cooked*), *rimanere* (*to remain*)/*rimasto* (*remained*)).

In the next section, we will try to detail this hypothesis through an investigation of the processes of production of regular and sub-regular verbs.

Chapter 4 .
Experiment 8. The production of regular and sub-regular verbal forms

4.1 Introduction

In Experiment 8 we investigated the processes of production of real regular and sub-regular forms from verbs of the 2nd and 3rd conjugation. The experiment had two main purposes:

1. to understand whether, and to what extent, the production of regular and sub-regular forms is sensitive to morpho-phonological similarity between regular and sub-regular verbs;
2. to verify whether the production of regular and sub-regular verbal forms is affected by the distribution of regular and sub-regular verbs within a specific inflectional class.

For what concerns the first aim, we expected to find that the morpho-phonological similarity interfered with the production of both regular and sub-regular verbs (Orsolini and Marslen-Wilson, 1997). Relative to the second goal, we hypothesized that the different distribution of regular and sub-regular verbs within the 2nd and the 3rd conjugation should determine an

asymmetry in processing, with slower latencies in the production of both regular forms from the 2nd conjugation and of sub-regular forms from the 3rd conjugation verbs, given the different levels of attractiveness of regular and sub-regular patterns within each class (Orsolini and Marslen-Wilson, 1997; Colombo et al., 2004).

4.2 Method

The experiment was based on a task of production of inflected forms within sentence contexts, based on the RSVP (Rapid serial visual presentation) paradigm. In the RSVP paradigm, participants see sequences of words, presented at a fixed fast rate on a computer screen. The task is usually associated with an additional task, which, in this case, consisted in the production of inflected verbal forms.

4.3 Participants

The experiment was completed by 40 students from the University of Salerno, native Italian speakers, aged between 19 and 32 years. Each participant took about 30 minutes to complete the experiment.

4.4 Procedure

The experimental task consisted in producing the correct inflected form of a verb, presented in the infinitive form.

A cross (indicating the fixation point) was presented at the centre of a white screen, accompanied by an acoustic stimulus. Then participants saw on the screen, one at a time, the constituents of a sentence. The target verb was presented in isolation, and highlighted in red. In sentence contexts requiring a compound form (e.g. the past tense or gerund), the target verb was preceded by the auxiliary verb, also shown in isolation. Participants were given 1 second to pronounce aloud the inflected form of the verb. In figure 4.1 an example of the experimental procedure is displayed.

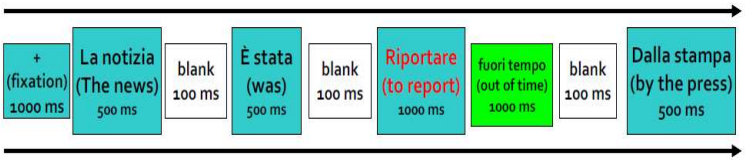

Figure 4.1. *Example of the experimental procedure.*

The reaction time corresponded to the interval between the appearance of the target stimulus and the onset of the response. The sentences were divided into

5 blocks of 54 items, each presented in a random order. Even the order of the sentences within each block was arranged randomly. The experiment was precede by a training session of 20 items.

4.5 Stimuli

The experimental list was based on 20 forms from regular and 20 forms from sub-regular Italian verbs (10 of the 2nd and 10 of the 3rd conjugation within each category). The inflected form to be produced corresponded either to the past participle or the present and future indicative: the regularity or sub-regularity status of each verb was considered in the basis of the expected form. The experimental list was created by pairing regular and sub-regular verbs of the same conjugation; they shared the final couple of syllables (and, in some cases, the syllabic code of the third last syllable) of the infinitive form (eg., "*svanire*" (*to vanish*) vs. "*svenire*" (*to faint*): in this case subjects had to produce, respectively, "*svaniscono*" (*they vanish*) and "*svengono*" (*they faint*)). We also created a control list consisting of 20 regular verbs (10 of 2nd and 10 of 3rd conjugation) morpho-phonologically different from any other sub-regular or irregular verb of the same inflectional class (e.g. "*temere*" (*to fear*), for which the

expected form was "*temono*" (*they fear*)) (see Appendix E for the complete experimental materials). The experimental and control lists were balanced for root frequency and inflected form in written language (CoLFIS, *Corpus e lessico di frequenza dell'italiano scritto*, Laudanna et al., 1995), for frequency of the inflected form in the spoken language (LIP, *Lessico di frequenza dell'Italiano parlato*, De Mauro, Mancini, Vedovelli and Voghera, 1994), for length in letters, in phonemes and in syllables, for the number of prefixed verbs within each list, and for the orthographic overlap between input form and expected form (see Table 4.1 for mean values of the parameters controlled in the experimental materials).

210 fillers were included in the experiment: 110 1st conjugation verbs, 45 2nd conjugation verbs and 55 3rd conjugation verbs. They constituted, together with the experimental and control lists, a total of 270 items.

stimuli	root frequency	written form frequency	spoken form frequency	length in letters	length in phonemes	length in syllables	prefixed verbs	orthographic overlap
regular verbs	142,55	16,65	1,05	8,9	8,5	3,8	16	0,7
sub-regular verbs	143,45	16,8	1,15	8,9	8,55	3,75	16	0,7
control verbs	145	15,4	1,4	8,9	8,55	3,9	14	0,7

Table 4.1. *Mean values for the relevant parameters controlled in Experiment 8.*

4.6 Equipment

The sentences were displayed on a screen connected to an IBM computer. The experiment run on the E-Prime software.

4.7 Results and discussion

The results showed that the production of sub-regular forms is slower than production of regular forms, and that forms from both experimental categories were slower than control regular forms. A two way ANOVA based on conditions (Control, Sub-regular and Regular) and conjugation (2^{nd}, 3^{rd}), was performed both on

reaction times and errors. For sake of conciseness, we will report only the results from the analysis by participants. In table 4.2 the mean reaction times of Experiment 8 are reported. The analysis on reaction times (RTs) showed a significant effect of condition ($F(2.78) = 32.8$, $p<.001$). LSD planned comparisons revealed longer Rts on sub-regulars than on regulars ($p<.001$), and on both sub-regulars and regulars than on controls ($p<.001$; $p<.001$). The effect of conjugation ($F(1.39) = 4.4$, $p<.05$), revealed longer RTs on 3rd than on 2nd conjugation verbs. Although the interaction between condition and conjugation was not significant, in LSD post hoc comparisons we observed slower RTs on sub-regular 3rd conjugation verbs compared to the 2nd conjugation verbs ($F(2.78) = .96$, $p <.05$) (see figure 4.2).

Reaction times (ims)	sub-reg	reg	ctrl
II conjugation	615	596	564
III conjugation	633	598	576

Table 4.2. *Mean reaction times in Experiment 8.*

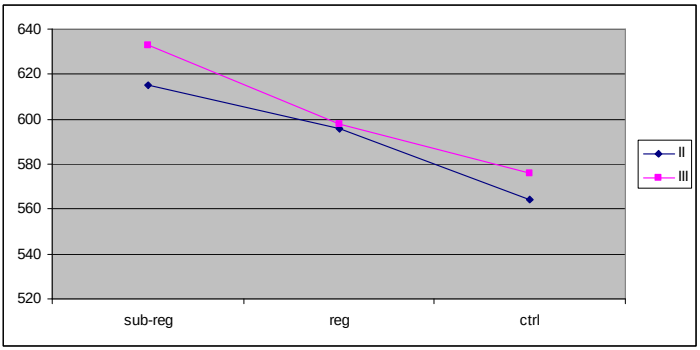

Figure 4.2. *Reaction times for conditions and conjugations in Experiment 8.*

In table 4.3 I report the percentages of errors of Experiment 8. In the analyses on errors, there was a significant effect of condition ($F(2.78) = 16.9$, $p<.001$). LSD tests revealed a higher error rate on sub-regular than on regular verbs ($p<.05$), and more errors on sub-regulars and regulars than on controls ($p<.001$; $p<.001$). The effect of conjugation ($F(1.39) = 7.6$, $p<.05$), is given by a greater number of errors on 3rd than on 2nd conjugation verbs. We observed a significant interaction between condition and conjugation ($F(2.78) = 9.5$, $p<.005$), resulting from a prevalence of errors on 2nd conjugation compared to 3rd conjugation control verbs ($p<.01$), and on 2nd conjugation compared to 3rd conjugation regular verbs ($p<.001$) (see figure 4.3).

Errors (in %)	sub-reg	reg	ctrl
II conjugation	16	20	13
III conjugation	20	11	8

Table 4.3. *Mean percentages of errors in Experiment 8.*

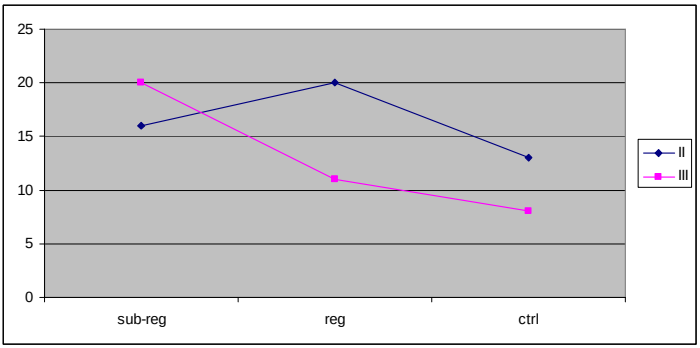

Figure 4.3. *Errors for condition and conjugation in Experiment 8.*

The quantitative analysis of errors confirmed the different pattern of results on 2nd and 3rd conjugation verbs: among sub-regulars, 3rd conjugation verbs had longer RTs than 2nd conjugation ones. On experimental and control regular categories, instead, we observed the opposite trend, with a higher number of errors on the 2nd than on the 3rd conjugation verbs.

In the qualitative analysis, we took into account, separately:

- errors based on hesitations or production of word fragments;
- omissions;
- errors based on the production of real words or non-words.

The errors based on responses (both words or non-words) which did not correspond to the expected form, have been further classified:

- morphological errors, based on the violation of one or more morphological features (person, number, tense), on regularization of a sub-regular root, or on sub-regularization or irregularization of a regular root);

phonological errors, based on an incorrect reading of the input stimulus, or on the production of a phonological string which was not related to the expected form. In table 4.4 I report the percentages of errors in the qualitative analyses on Experiment 8.

The analysis on hesitations showed a significant effect of condition ($F(2.78) = 3.6$, $p<.05$). LSD tests showed a greater number of errors on sub-regular verbs than on regular ($p<.01$) and control ones ($p<.01$). The significant interaction between condition and conjugation ($F(2.78)$

= 7.1, p<.001) suggests that the difference is due to a higher number of errors on 3rd conjugation sub-regular as compared to 3rd conjugation control verbs (p<.001), and regular verbs (p<.001). LSD Post-hoc comparisons also showed more errors on sub-regular 3rd conjugation verbs than on sub-regular 2nd ones (p<.01), and, among control verbs, on 2nd conjugation compared to 3rd (p<.05).

errors (in %)	ctrl II	ctrl III	sub-reg II	sub-reg III	Reg II	Reg III
hesitations/ word fragments	4,5	1,75	4,5	8,25	5,75	3,5
omissions	4,25	2,5	9,25	5	8,25	5
word errors	2,5	1,75	1,75	1,25	4,25	1
non-word errors	0,75	0,25	0,25	5	1	0
morphological errors	1,75	1,75	1,5	5,75	1	0,25
phonological errors	1,25	0,25	0,5	0,5	4,25	0,75

Table 4.4. *Qualitative analysis: mean percentages of errors in Experiment 8.*

The ANOVA on word and non word errors was based on three factors (type of error, conjugation and condition). The effect of type revealed a greater number of word vs. non-word errors ($F(1.39) = 5.12$, $p<.05$). The interaction between type and condition ($F(2.78) = 8.4$, $p<.005$) derives from more non-word errors on sub-regulars than on regulars ($p<.001$) and controls ($p<.001$), and a marginally significant prevalence of non-word errors among sub-regular verbs ($p<.07$), and of word errors among regulars ($p<.001$) and controls ($p<.01$). The interaction between type and conjugation ($F(1.39) = 17.1$, $p<.005$), is due, as observed in LSD planned comparisons, to higher rate of word errors among 2nd conjugation verbs ($p<.01$), vs. a dominance of word errors on the 2nd conjugation ($p<.005$), and of non-word errors on the 3rd conjugation ($p<.05$). Finally, the three-way interaction between type, conjugation and condition ($F(2.78) = 3.8$, $p<.05$), tell us that, among regular verbs, a greater number of word errors was made on the 2nd than on the 3rd conjugation ($p<.01$), and a higher number of word errors in the 2nd conjugation ($p<.001$). By contrast, in the sub-regular category we found more non-word errors on the 3rd than on the 2nd conjugation ($p<.001$), and a higher

number of non-word than word errors among the 3rd conjugation verbs (p<.001).

A three factor ANOVA (type of errors, condition and conjugation) on morphological and phonological errors showed more morphological than phonological errors ($F(1.39) = 4.8$, $p<.05$). The interaction between type and condition ($F(2.78) = 14.8$, $p<.005$) was due, as observed in LSD post hoc tests, to a higher number of morphological errors on sub-regulars than on regulars ($p<.005$) and controls ($p<.005$), and a greater number of phonological errors on regulars than on sub-regulars ($p<.005$) and controls ($p<.01$). On sub-regular verbs, we observed more morphological than phonological errors ($p<.001$). Regular verbs showed the opposite pattern, with a prevalence of phonological over morphological errors ($p<.005$). Finally, the interaction between type and conjugation ($F(2.78) = 15.4$, $p<.005$) was detected: while the number of morphological errors was greater in the 3rd conjugation verbs ($p<.005$), phonological errors prevailed in the 2nd conjugation verbs ($p<.005$).

Among the various results just reported, the most interesting seem to be those pertaining to errors resulting in production of incorrect forms. Indeed, the high concentration of non-word/morphological errors among sub-regular verbs is partially due to the

presence of errors of regularization of 3rd conjugation sub-regular verbs (e.g., **assaliscono* instead of *assalgono* (*they assail*), based on the regularization of a sub-regular verb through the application of the regular 3rd conjugation's inflectional pattern).

The evidence from a production task seems to confirm the hypothesis of an effect related to the morpho-phonological similarity between regular and sub-regular verbs. If we analyze the different patterns of inhibition observed among verbs from conjugations 2 and 3, it seems that the influence of regular or sub-regular models is conditioned by the distributional properties of each inflectional class. Among 3rd conjugation verbs, regular ones were faster and more accurately produced, and sub-regular ones were often regularized. Among the 2nd conjugation verbs we found the opposite pattern, since sub-regular paradigms were facilitated with respect to regular ones. These data may be explained by the hypothesis of the attractiveness of inflectional patterns: regular 3rd conjugation verbs and sub-regular 2nd conjugation verbs resulted to be more attractive than regular 2nd conjugation and sub-regular 3rd conjugation verbs. Control regular verbs, which had no sub-regular competitors, were the easiest to produce.

To sum up, the results of the experiment on the production of real inflected forms, together with the data on the recognition of regularized and sub-regularized pseudo-forms, are not compatible with a dichotomic distinction about the representation of regular and irregular verbs. Our results seem to indicate similar mechanisms of processing for inflected forms belonging to regular and sub-regular families, and they challenge the hypothesis put forward by Say and Clahsen (2001), that only regular forms of the 1st conjugation are processed through the application of a concatenative rule, while all other regular and irregular inflected forms are stored as whole forms.

Focusing more directly on the experiment of production of verbal inflected pseudo-forms reported by Say and Clahsen (2011), we noted several methodological flaws of the experimental design, which could have considerably shaped their results. In the next chapter we will present the results of an experiment of production of pseudo-forms, in which we tried to replay and extend the Say and Clahsen's experimental design, overcoming the methodological inadequacies of their research.

Chapter 5 .
Experiment 9. Generalizing properties of regular and sub-regular patterns of Italian verbal system

5.1 Introduction

In Chapter 2 we discussed the results of an experiment of production of past-participles of Italian pseudo-verbs (Say and Clahsen, 2001). In the experiment, each pseudo-verb was similar or not to a regular or irregular verb of the 2nd and 3rd conjugation. The pseudo-verbs were presented within sentence contexts, in forms (1st or 2nd singular person or 1st plural person forms) that did not contain the thematic vowel. In all the experimental categories (but particularly on verbs with low similarity), the authors observed a strong tendency to choose the regular pattern of the 1st conjugation (e.g. *bremato instead of *bremuto). They also found more expected responses on pseudo-verbs similar to high-frequency verbs, except in the condition of similarity to verbs of the 2nd conjugation containing irregular roots.
Beyond the already mentioned criticism raised by Eddington (2002) about the choice of not including pseudo-verbs similar to 1st conjugation verbs, it is

possible to underline other methodological flaws in the experimental design used by Say and Clahsen. First, experimental categories were not balanced for number of stimuli. Furthermore, they established the similarity of pseudo-verbs to real verbs on the basis of a "rhyme criterion", according to which "a novel verb was considered similar to an existing verb, if it shared the final vowel and consonant(s) of the root" (Say and Clahsen, 2001, p. 109).

In figure 5.1 I reproduce a table in which the authors reported some examples of the experimental pseudo-verbs. Analyzing these examples, one can easily observe how the rhyme criterion does not allow to capture unambiguous similarities: the pseudo-form **cendiamo*, which was supposedly similar to *prendiamo* (*we take*), is also similar to a 1st conjugation form like *ceniamo* (*we have dinner*), a 3rd conjugation form such as *condiamo* (*we flavour*), and a regular 2nd conjugation form like *vendiamo* (*we sell*); in a similar way, **bremiamo*, similar to the regular 2nd conjugation *temiamo* (*to fear*), is also similar to the 1st conjugation forms *bramiamo* (*we desire*) and *tremiamo* (*we tremble*). Furthermore, the "no similarity" example **zuisdiamo* is

a form based on an almost phonotactically unacceptable sequence of phonemes in Italian [2].

Condition	Novel verb	Existing verb	No.
1. similarity to irregular 2nd conj.	*cendiamo*	*prendiamo* 'we take'	20
2. similarity to irregular 3rd conj.	*suffriamo*	*soffriamo* 'we suffer'	10
3. similarity to regular 2nd conj.	*bremiamo*	*temiamo* 'we fear'	20
4. similarity to regular 3rd conj.	*rinferiamo*	*riferiamo* 'we refer'	20
5. no similarity	*zuisdiamo*		12
		Total	**82**

Table 5.1. *Examples of experimental stimuli of the experiment by Say & Clahsen (2001)*

[2] As to the similarity between each pseudo-verb and one or more existing verbs, the authors themselves admitted that, in some cases, the rhyme was shared by other groups of verbs (of lower frequency) following different inflectional models.

In sum, it is possible that the results of the experiment could have been influenced by a set of uncontrolled factors. We conducted an experiment similar to the one reported by Say and Clahsen, but based on an extended and more controlled experimental design.

5.2 Method

The goal of our experiment was to investigate the attractivity of regular and sub-regular inflectional patterns of Italian, by leading participants to generalize them through the production of pseudo-past participles. The pseudo-verbs were presented in inflected forms that did not contain the thematic vowel, which provides phonological cues for class membership. Each experimental pseudo-verb was either similar to a high or low frequency verb of a single conjugation, or similar to a 1st conjugation and to a 2nd or 3rd conjugation verb, or not similar to any real verb. We expected to observe that the generalization of inflectional patterns was influenced by the similarity of the pseudo-verbs to existing verbs, as well as by the morpho-phonological consistency of their family.

5.3 Stimuli

The input pseudo-forms were created by substituting, adding or deleting a letter from a real Italian verb form. They consisted of pseudo-inflected forms of the 1st or 2nd singular person or 1st plural person of the present indicative.

The experimental list contained 148 stimuli, divided in 12 categories:

1. pseudo-verbs similar to high frequency regular 1st conjugation verbs (e.g. **ronfermo*, similar to *confermo* (*I confirm*);
2. pseudo-verbs similar to low frequency regular 1st conjugation verbs (e.g. **prizzico*, similar to *pizzico* (*I pinch*);
3. pseudo-verbs similar to high frequency regular 2nd conjugation verbs (e.g. **tatteniamo*, similar to *tratteniamo* (*we keep*);
4. pseudo-verbs similar to low frequency regular 2nd conjugation verbs (e.g. **itesso* similar to *intesso* (*I interweave*);
5. pseudo-verbs similar to high frequency sub-regular 2nd conjugation verbs (e.g. **riviolgo*, similar to *rivolgo* (*I address*);

6. pseudo-verbs similar to low frequency sub-regular 2nd conjugation verbs (e.g. **pecludiamo* similar to *precludiamo* (*we preclude*);
7. pseudo-verbs similar to high frequency regular 3rd conjugation verbs (e.g. **evvertiamo*, similar to *avvertiamo* (*we inform*);
8. pseudo-verbs similar to low frequency regular 3rd conjugation verbs (e.g. **pesagiamo* similar to *presagiamo* (*we portend*);
9. pseudo-verbs not similar to real Italian verbs (e.g. **bledongo*);
10. pseudo-verbs similar to a 1st conjugation real verb and, at the same time, to a 2nd or a 3rd conjugation verb of a similar frequency (e.g. **tugliamo*, similar to *tagliamo* (*we cut*) and *togliamo* (*we remove*); **bormiamo*, similar to *formiamo* (*we set up*) and to *dormiamo* (*we sleep*)). The real verbs differed from each other according to only one letter, which was substituted in order to create the pseudo-verb.

The complete list of experimental stimuli is reported in Appendix F. We could not create categories of pseudo-verbs similar to high and low frequency sub-regular

verbs of the 3rd conjugation, because of the small number of sub-regular families in this inflectional class. All the experimental pseudo-verbs were inserted within the same sentence:

Oggi evvertiamo, ieri abbiamo/siamo
.....
(*today evvertiamo, yesterday we have/have been*
.....)

Oggi prizzico, ieri ho/sono .....
(*today prizzico, yesterday I have/have*
been.....)

The verbs involved in the categories from 1 to 8 were balanced for root frequency in written language (on the basis of a corpus of almost 4.000.000 occurrences, CoLFIS, *Corpus e lessico di frequenza dell'italiano scritto*, Laudanna et al., 1995). The input pseudo-forms of condition 1 to 9 were balanced according to length in letters. Furthermore, we controlled the number of inflected forms of the 1st and 2nd singular person and of the 1st plural person within each category. Finally, the same types of transformations (4 substitutions, 4 additions and 4 deletions) were applied on the real verbs

of all categories (see Table 5.2 for mean values of the parameters controlled in the experimental materials).

stimuli	root frequency	length
similar to I con. high frequency	357,4	9
similar to I con. low frequency	13	9
similar to II con. sub-regular high frequency	359,7	9,2
similar to II con. sub-regular low frequency	12,7	9,2
similar to II con. regular high frequency	372,5	9,1
similar to II con. regular low frequency	12,5	9
similar to III con. regular high frequency	358,1	9
similar to III con. regular low frequency	13	9
not similar		9

Table 5.2. *Mean values for root frequency and length of input forms of categories 1-9.*

The choice of pseudo-inflected forms of the 1st plural person as input was motivated by the fact that many present indicative 1st and 2nd singular person forms of the 3rd conjugation contain the stem augmented in *–isc*

(e.g. *finisco* (*I finish*), which would have provided adjunctive information on class membership on pseudo-forms. On the other hand, our 1st plural person pseudo-forms were exposed to a bias toward the 1st conjugation: all these pseudo-forms, indeed, terminate with the segment *–iamo*, so it was sufficient, for participants, to substitute the letter *-m-* with the letter *-t-* in order to obtain a pseudo-past participle ending in *–iato*. Such a problem appeared nonetheless to be unsolvable, unless to eliminate the categories of high and low frequency regular 3rd conjugation pseudo-verbs.

The pseudo-verbs of category 10 were created on the basis of pairs of 1st and 2nd or 3rd conjugation verbs of similar frequency (see table 5.3).

stimuli	I conjugation root frequency	II- III conjugation root frequency
similar to I and II conjugation	85,75	99,75
similar to I and III conjugation	78,625	75

Table 5.3. *Mean values for root frequency of real verbs of reference, in categories 10-11.*

We controlled the uniqueness of similarity between each input pseudo-form and the real inflected form by using an "extended" n-count, computed on real words obtainable by substituting, adding or deleting a letter in each position of the pseudo-form. On the basis of this criterion, we excluded pseudo-forms which were similar to more than one real verbal form.

5.4 Procedure

A booklet of 11 pages was given to each subject. The first page described the instructions of the task, the other pages contained the experimental sentences (15 sentences on each page, 13 sentences on the last one). Subjects had to read the first part of each sentence (containing the input pseudo-form), and then complete the second part with the pseudo-past participle. Each sentence suggested both the auxiliary verbs *avere* (*to have*) and *essere* (*to be*).Subjects were asked to write only one response for each pseudo-verb, to choose the response as quickly as possible, and to not read again the responses previously given. Furthermore, the instructions contained an example of pseudo-verb with several possible pseudo-participles, both regular and sub-regular.

5.5 Results and discussion

All responses ending in *–ato*, *-ito* and *–uto* were considered regularizations of 1st, 2nd or 3rd conjugation. Responses ending in *-so*, *-so*, *-sto*, *-sso*, *-to*, *-nto*, *-sto* or *-tto* were considered as sub-regularizations. Responses based on a modified form of the verbal root followed by a regular or sub-regular ending were classified as regularizations or sub-regularizations, according to the same criterion used for the other responses. Finally, responses based on forms not similar to any existing past participle were excluded by the analyses.

The results showed a strong tendency to generalize inflectional patterns on the basis of the morpho-phonological similarity of pseudo-verbs to existing verbs. The choice of regular and sub-regular patterns of the 2nd and the 3rd conjugation was strongly influenced by formal similarity, while the generalizations of the 1st conjugation pattern were highly frequent in all experimental categories. In Table 5.4 I report the percentage of responses based on the generalizations of regular and sub-regular patterns, in all experimental categories.

Stimuli	I	II	III	sub-regularizations
similar to I con. high frequency	78,4	8,0	6,4	4,2
similar to I con. low frequency	81,4	8,0	7,2	3,4
similar to II con. sub-regular high frequency	24,6	11,4	6,8	57,2
similar to II con. sub-regular low frequency	26,5	14,4	6,8	51,5
similar to II con. regular high frequency	26,5	57,2	8,3	6,4
similar to II con. regular low frequency	29,9	51,5	11,0	6,8
similar to III con. regular high frequency	27,7	9,1	59,5	3,8
similar to III con. regular low frequency	37,5	8,0	45,5	9,1
not similar	56,4	13,6	10,6	19,3
similar to I and II conjugation	59,7	14,8	12,5	13,1
similar to I and III conjugation	63,6	8,5	18,8	8,5

Table 5.4. *percentages of sub-regularizations and regularizations of 1st 2nd and 3rd conjugations, in all experimental categories.*

Although the 1st conjugation regular pattern was generally chosen more frequently than others, we observed that each inflectional pattern prevailed among the morpho-phonologically consistent pseudo-verbs. Say and Clahsen, on the contrary, had found a predominance of the 1st conjugation responses in all experimental categories. Furthermore, among the pseudo-verbs of the "No similarity" condition, they observed 90% of regularizations corresponding to the 1st conjugation pattern, against 4% of regularization for each of the other conjugations, and 2% of sub-regularizations. As shown in Table 5.4, we found much less 1st conjugation-like responses, and a considerably larger number of responses based on sub-regularizations. A similar result emerged on the categories "Similar to 1st and 2nd conjugation" and "Similar to 1st and 3rd conjugation".

On regular 2nd and 3rd conjugation pseudo-verbs, Say and Clahsen observed higher percentages of expected responses on high frequency conditions, while we observed such a result only on regular 3rd conjugation pseudo-verbs.

On regular pseudo-verbs of the three inflectional classes we conducted a repeated measures ANOVA on type of response (regularizations of 1st, 2nd or 3rd

conjugation, and sub-regularizations), with two predictors (conjugation and frequency). We observed a significant effect of type of response by participants ($F(6.378) = 110.85$, $p<.001$), and by items ($F(6.198) = 88.2$, $p<.001$), based on a prevalence of 1st conjugation generalizations. We also found a main effect of conjugation, both by participants ($F(6.378) = 93.8$, $p<.001$) and by items ($F(6.198) = 74.7$, $p<.001$). We did not find any effect of frequency, but the LSD test on pseudo-verbs of 3rd conjugation revealed a higher percentage of expected responses in the "high frequency" condition ($p<.005$ by participants, $p<.01$ by items), and a higher number of 1st conjugation regularizations in the low frequency condition ($p<.05$ by participants, $p<.07$ by items).

On sub-regular pseudo-verbs of the 2nd conjugation, a main effect of type of response ($F(3.63) = 36.3$, $p<.001$) by participants, ($F(3.66) = 20.24$ $p<.001$) by items) was found. The effect of frequency was not significant.

In the ANOVA on No Similarity condition, we observed an effect of Type of Response by participants ($F(3.63) = 19.97$, $p<.001$) and by items ($F(3.33) = 22.24$, $p<.001$)), which revealed a higher rate of 1st conjugation responses as compared to the other patterns.

Finally, the ANOVA on pseudo-verbs similar to 1st and 2nd or 3rd conjugation, showed an effect of type of response by participants ($F(3.126) = 59.4$, $p<.001$), and by items ($F(3.42) = 40.1$, $p<.001$).

Our results show a less marked separation between the 1st conjugation regular pattern and the other regular and sub-regular inflectional patterns: the "default effect" observed by Say and Clahsen was weaker than that of morpho-phonological similarity. Even in the "No similarity" condition, the distribution of responses is not consistent with a single pattern of default. Furthermore, the high concentration, in our experiment, of forms ending in *-iamo* in all experimental categories, could be sufficient to determine a bias toward the 1st conjugation.

In sum, our results are only partially consistent with those obtained by Say and Clahsen (2001). Rather than demonstrating that the 1st conjugation pattern is the only productive pattern of Italian, they reveal different levels of generalizability, probably determined by the numerosity and internal consistency of each inflectional family.

Concluding remarks

The experiments presented in the previous chapters were aimed at investigating the interaction between morpho-phonological regularity and morpho-phonological similarity in the processing of Italian verbal forms. The predictability of some sub-regular patterns, shared by groups of morpho-phonologically similar verbs, makes it possible to hypothesize that these patterns are processed through the application of rules, similarly to what happens for regular models (Chomsky and Halle, 1968).

Minimalist Morphology theory (Wunderlich and Fabri, 1995) defined sub-regular patterns as "lexical restricted inflection", encoded in the lexical entry as additive information. They contrast with regular models, based on combinatorial procedures.

Albright and Hayes (2002) provided a common interpretation for regular and sub-regular inflections, claiming that all morphological processes are based on phonological rules which describe a change through the phonological features of a verbal paradigm, and can be generalized on the basis of the morphological features shared by forms which follow the same inflectional pattern.

Dual Mechanism theories assume a rigid, cross-linguistic dichotomy between a regular default pattern and "irregular" patterns. They do not distinguish between idiosyncratic irregular patterns and sub-regular ones; irregular forms would be all stored as whole forms. However, a strict separation between default class and irregular patterns appears to be inadequate for Italian verbal system, which is characterized by multiple regular patterns and highly phonologically consistent sub-regular families.

In experiments 1 to 7, we tested the effect of morpho-phonological similarity on all the three conjugations of Italian, finding that regular and sub-regular patterns interfere with each other in the recognition of both regularized and sub-regularized pseudo-forms. These results led us to hypothesize that the generalizability of inflectional patterns can be defined on the basis of their attractiveness, which is not based on regularity, but on numerosity, frequency and morpho-phonological variability of the verbs sharing the same inflectional pattern. In Experiment 8 we investigated whether the production of regular and sub-regular forms is sensitive to morpho-phonological similarity between regular and sub-regular verbs. The results revealed a disadvantage in the production of regular verbs of 2nd conjugation

and of sub-regular verbs of 3rd conjugation, indicating that the prevalence of regular or sub-regular verbs determines the dominant patterns within each inflectional class. Finally, in Experiment 9 we tested the generalizability of regular and sub-regular patterns of Italian on novel verbs. We observed a strong effect of morpho-phonological similarity of pseudo-verbs to existing verbs. Furthermore, we found that, although the 1st conjugation regular pattern was the most widely generalized, it does not act as the unique pattern of default when pseudo-verbs are not similar to real verbs. Therefore, our data diverge from the predictions made by Say and Clahsen (2001), who identify the 1st conjugation as the default class, and state that all other forms are processed as irregular.

On the basis of the experimental data discussed so far, it seems that the processing of regular and sub-regular verbs should not necessarily be associated to a two route, rule-governed system. In accordance to Burzio (1998), the relationship between allomorphs can be interpreted on the basis of multiple correspondences between surface forms and words fragments. Under this perspective, the strength of an inflectional pattern depends on the number and frequency of allomorphs sharing the same pattern of phonological alternation.

Appendix A.
Experimental and control stimuli of Experiments 1 and 2

infinite	category	sub-regular model	exp item	control item
aprire	regularized sub-regular		aprito	aprido
chiarire	sub-regularized regular	apparire/apparso	chiarsa	chiarpa
contraddire	regularized sub-regular		contraddita	contraddima
convenire	regularized sub-regular		convenito	convenido
coprire	regularized sub-regular		coprito	coprigo
disdire	regularized sub-regular		disdita	disdima
esaurire	sub-regularized regular	apparire/apparso	esaursa	esaurna
fallire	sub-regularized regular	seppellire/sepolto	falta	falga
favorire	sub-regularized regular	morire/morto	favorto	favorco
finire	sub-regularized regular	venire/venuto	finuta	finuva
impedire	sub-regularized regular	dire/detto	impedetto	impedetro
morire	regularized sub-regular		morita	morica
offrire	regularized sub-regular		offrito	offrigo
pervenire	regularized sub-regular		pervenito	pervenido
preferire	sub-regularized regular	apparire/apparso	preferso	preferno

riapparire	regularized sub-regular		riapparito	riapparico
ribadire	sub-regularized regular	dire/detto	ribadetto	ribadetro
ricomparire	regularized sub-regular		ricomparito	ricomparico
riferire	sub-regularized regular	morire/morto	riferto	riferco
scoprire	regularized sub-regular		scoprito	scoprico
soffrire	regularized sub-regular		soffrito	soffrigo
suggerire	sub-regularized regular	morire/morto	suggerto	suggerco
tradire	sub-regularized regular	dire/detto	tradetto	tradelto
trasferire	sub-regularized regular	apparire/apparso	trasferso	trasferno

Appendix B.
Experimental and control stimuli of Experiments 3 and 4

infinite	sub-regular model	exp item	control item
afferrare	trascorrere/trascorso	afferso	afferno
allargare	spargere/sparso	allarso	allarno
azzardare	ardere/arso	azzarso	azzarno
cancellare	eccellere/eccelso	cancelso	canceldo
comandare	accendere/acceso	comaso	comalo
eliminare	rimanere/rimasto	elimisto	elimisco
immedesimare	esprimere/espresso	immedesso	immedesco
inciampare	rompere/rotto	inciatto	inciatro
liquidare	ridere/riso	liquiso	liquido
regalare	valere/valso	regalso	regaldo
ribellare	eccellere/eccelso	ribelso	ribeldo
sbagliare	scegliere/scelto	sbalto	sbaldo
scivolare	valere/valso	scivolso	scivoldo
scrutare	discutere/discusso	scrusso	scrusmo
separare	parere/parso	separso	separdo
sfidare	ridere/riso	sfiso	sfiro
sorvegliare	scegliere/scelto	sorvelto	sorveldo
tramandare	accendere/acceso	tramasa	tramaca
valutare	discutere/discusso	valusso	valusmo
vergognare	spegnere/spento	vergonto	vergondo

Appendix C.

Experimental and control stimuli of Experiments 5 and 6

infinite	sub reg model	exp item	contr item
abbagliare	sciogliere/sciolga	abbalga	abbalfa
allenare	tenere/tenga	allenga	allenca
assomigliare	sciogliere/sciolgo	assomilgo	assomilmo
celare	valere/valga	celga	celpa
consigliare	sciogliere/sciolga	consilga	consilpa
consolare	valere/varrai	consorrai	consoppai
cucinare	tenere/tengo	cucingo	cucinzo
eliminare	tenere/terrei	elimirrei	eliminnei
emanare	tenere/terrei	emarrei	emappei
frenare	tenere/tenga	frenga	frenca
isolare	valere/varreste	isorreste	isobbeste
mescolare	valere/valgo	mescolgo	mescolfo
pedalare	valere/valga	pedalga	pedalfa
regalare	valere/varremmo	regarremmo	regabbemmo
rovinare	tenere/terrebbe	rovirrebbe	rovippebbe
sbagliare	sciogliere/sciolgo	sbalgo	sbalpo
scatenare	tenere/terrei	scaterrei	scatennei
seminare	tenere/tengo	semingo	seminzo
sfilare	valere/valgo	sfilgo	sfilco
stilare	valere/varreste	stirreste	stibbeste

Appendix D.
Experimental and control stimuli of Experiment 7

experimental category	sub-regular model	experimental prime	experimental target	Conj.	control prime	control target
sub-regularized-regulars	venire/vengo	ammonire	ammongo	III	capinere	capingo
regularized irregulars		andate	anda	I	fosfato	fosfa
regularized sub-regulars		apri	aprito	III	ginepri	gineprita
regularized sub-regulars		arde	arduto	II	orde	orduto
regularized sub-regulars		attenuto	attena	II	attonito	attona
regularized sub-regulars		avvalevi	avvalo	II	emotivi	emoto
regularized irregulars		bere	biamo	II	cere	ciamo
regularized irregulars		convivo	convivuto	II	cattivo	cattivuto
sub-regularized-regulars	ridere/riso	crede	cresi	II	erede	erese
sub-regularized-regulars	venire/vengo	cucino	cucingo	I	cuscino	cuscingo
sub-regularized-regulars	tacere/ tacciono	cucire	cucciono	III	lacere	lacciono
regularized sub-regulars		detenuto	deteni	II	cognato	cogna
regularized irregulars		dovevi	doviamo	II	longevi	longiamo
sub-regularized-regulars	venire/ vengono	elimina	elimingono	I	lamina	lamingono

regularized irregulars		iscrivere	iscrivuta	II	cadavere	cadavuta
regularized irregulars		morivi	moriscono	III	estivi	estiscono
regularized irregulars		muovo	muovute	II	rovo	rovute
regularized sub-regulars		ottenuti	otteno	II	appetiti	appeto
sub-regularized-regulars	ridere/ riso	possedevo	possesa	II	positivo	posisa
regularized irregulars		potuti	potono	II	statuti	statono
sub-regularized-regulars	presumere/ presunto	premo	prente	II	stremo	strente
sub-regularized-regulars	ridere/ riso	procede	procesa	II	omicide	omicisa
regularized sub-regulars		ricopro	ricoprita	III	capro	caprita
regularized sub-regulars		ride	riduto	II	modi	moduto
regularized irregulars		rifate	rifiamo	I	folate	foliamo
regularized irregulars		rinasco	rinasciuta	II	fresco	fresciuta
sub-regularized-regulars	perdere/ perso	ritarda	ritarso	I	leopardi	leoparso
regularized irregulars		riuscire	riusci	III	viscere	visci
sub-regularized-regulars	salire/ salgo	rivela	rivelgo	I	candela	candelgo
regularized sub-regulars		salito	salisco	III	quesito	quesisco
regularized sub-regulars		sceglie	scegliono	II	caviglie	cavigliono
regularized sub-regulars		scioglie	sciogliono	II	doglie	dogliono
regularized irregulars		smuovo	smuovuta	II	stuolo	stuoluta
regularized irregulars		spegne	spegnuto	II	cicogne	cicognuto

sub-regularized-regulars	salire/salgo	stabilivo	stabilgo	III	giulivo	giulgo
sub-regularized-regulars	Apparire/ apparso	supera	superso	I	vipera	viperso
sub-regularized-regulars	venire/ vengono	svanito	svangono	III	granito	grangono
sub-regularized-regulars	salire/ salgo	svilire	svilgo	III	balere	balgo
regularized sub-regulars		tendi	tenduto	II	sponde	sponduto
regularized sub-regulars		tingeva	tingiuto	II	gengiva	gengiuto
regularized sub-regulars		toglie	togliono	II	figlie	figliono
regularized irregulars		udivo	udono	III	ulivo	ulono

Appendix E.
Experimental and control stimuli of Experiment 8

category	Conj.	input form	expected form
experimental regular	II	abbattere (to pull down)	abbattuta (pulled down)
experimental regular	II	accadere (to happen)	accaduto (happened)
experimental sub-regular	II	accendere (to turn on)	accesi (turned on)
control regular	III	acuire (to heighten)	acuito (heightened)
control regular	II	adempiere (to fulfil)	adempiuto (fulfilled)
experimental regular	III	ammonire (to warn)	ammonito (warned)
experimental sub-regular	III	assalire (to assail)	assalgono (they assail)
experimental sub-regular	III	benedire (to bless)	benedicono (they bless)
experimental regular	II	benvolere (to endear)	benvoluto (endeared)
experimental regular	II	combattere (to fight)	combattuto (fought)
experimental sub-regular	III	comparire (to appear)	comparso (appeared)
control regular	II	competere (to compete)	competono (they compete)
control regular	II	compiere (to accomplish)	compiuto (accomplished)
experimental sub-regular	II	concludere (to conclude)	concluso (concluded)
experimental sub-regular	II	condividere (to share)	condiviso (shared)
experimental sub-regular	III	convenire (to agree)	convenuto (agreed)
experimental sub-regular	II	corrispondere (to correspond)	corrisposto (corresponded)

experimental regular	II	cuocere (to cook)	cuociono (they cook)
experimental regular	III	definire (to define)	definiscono (defined)
experimental sub-regular	II	dividere (to divide)	divisi (divided)
control regular	III	dormire (to sleep)	dormono (they sleep)
experimental sub-regular	II	equivalere (to be equivalent)	equivalso (been equivalent)
experimental sub-regular	II	escludere (to exclude)	esclusa (excluded)
control regular	III	eseguire (to carry out)	eseguita (carried out)
control regular	III	esordire (to debut)	esordito (debuted)
experimental sub-regular	II	estromettere (to proscribe)	estromesso (proscribed)
experimental regular	II	godere (to enjoy)	goduto (enjoyed)
control regular	III	impazzire (to go crazy)	impazziranno (they will go crazy)
experimental regular	III	inasprire (to exacerbate)	inasprito (exacerbated)
experimental sub-regular	III	intervenire (to intervene)	interverranno (they will intervene)
control regular	II	irrompere (to break in)	irrompono (broken in)
experimental sub-regular	II	persuadere (to convince)	persuaso (convinced)
experimental regular	II	possedere (to own)	posseduto (owned)
experimental sub-regular	III	predire (to predict)	predetto (predicted)
experimental sub-regular	II	prevalere (to prevail)	prevalso (prevailed)
experimental sub-regular	III	provenire (to come from)	provengono (they come from)
experimental sub-regular	III	ricomparire (to reappear)	ricompaiono (they reappear)
control regular	III	riempire (to fill)	riempita (filled)
control regular	II	rileggere (to reread)	rileggeranno (they reread)
experimental sub-regular	III	rinvenire (to discover)	rinvenuto (discovered)

experimental regular	III	ripulire (to clean again)	ripuliscono (they clean again)
experimental sub-regular	III	risalire (to go up)	risalgono (they go up)
control regular	II	riscuotere (to cash)	riscuotono (they cash)
control regular	III	risentire (to be affected)	risentono (they are affected)
control regular	III	rivestire (to cover)	rivestono (they cover)
experimental regular	II	rivolere (to want back)	rivoluto (wanted back)
experimental regular	III	sbiadire (to fade)	sbiadito (faded)
experimental regular	II	scadere (to expire)	scaduto (expired)
experimental regular	III	schiarire (to lighten)	schiarito (lightened)
control regular	III	scolpire (to sculpt)	scolpiscono (they sculpt)
control regular	II	scorrere (to scroll)	scorrerai (you will scroll)
control regular	II	sorridere (to smile)	sorridono (they smile)
experimental regular	III	sparire (to disappear)	spariscono (they disappear)
control regular	II	spendere (to spend)	spendono (they spend)
control regular	II	spremere (to squeeze)	spremerai (you will squeeze)
experimental regular	III	svanire (to vanish)	svaniscono (they vanish)
experimental regular	II	svendere (to sell out)	svenduto (sold out)
experimental regular	III	svilire (to debase)	sviliscono (they debase)
control regular	II	temere (to fear)	temono (they fear)
experimental regular	III	tradire (to betray)	tradiscono (they betray)

Appendix F.

Experimental and control stimuli of Experiment 9

category	target	verb of reference	Conj.	variation	expected form
similar I-II conjugation	abbarro	abbassare/ abbattere	I-II	substitution	
II conjugation regular high frequency	abbiattiamo	abbattere	II	addition	abbiattuto
III conjugation regular low frequency	abbrelliamo	abbellire	III	addition	abbrellito
II conjugation regular low frequency	accrasco	accrescere	II	substitution	accrasciuto
III conjugation regular high frequency	alderiamo	aderire	III	addition	alderito
not similar	alevistiamo				
similar I-III conjugation	ammanciamo	ammantare/ ammansire	I-III	substitution	
I conjugation high frequency	ammiazzo	ammazzare	I	addition	ammiazzato
II conjugation regular high frequency	appateniamo	appartenere	II	subtraction	appatenuto
III conjugation regular low frequency	appattiamo	appiattire	III	subtraction	appattito
III conjugation regular low frequency	apprassiamo	appassire	III	addition	apprassito
II conjugation regular low frequency	astreniamo	astenere	II	addition	astrenuto
III conjugation regular high frequency	attibuiamo	attribuire	III	subtraction	attibuito
II conjugation regular low frequency	attreniamo	attenere	II	addition	attrenuto
I conjugation low frequency	azzarriamo	azzardare	I	substitution	azzarrato
similar I-II conjugation	bergo	vergare/tergere	I-II	substitution	
not similar	bescardo				
not similar	bledongo				

similar I-III conjugation	blundiamo	blindare/ blandire	I-III	substitution	
similar I-III conjugation	bormiamo	dormire/ formare	I-III	substitution	
not similar	castuniamo				
II conjugation regular low frequency	comiaciamo	compiacere	II	subtraction	comiaciuto
I conjugation high frequency	conegno	consegnare	I	subtraction	conegnato
II conjugation regular high frequency	coneniamo	contenere	II	subtraction	conenuto
II conjugation irregular high frequency	conistiamo	consistere	II	subtraction	conistito
similar I-II conjugation	contorliamo	contornare/ contorcere	I-II	substitution	
III conjugation regular high frequency	cotruiamo	costruire	III	subtraction	cotruito
II conjugation irregular low frequency	cringiamo	cingere	II	addition	crinto
I conjugation low frequency	cronciamo	conciare	I	addition	cronciato
III conjugation regular low frequency	curpiamo	carpire	III	substitution	curpito
similar I-III conjugation	dalliamo	ballare/fallire	I-III	substitution	
II conjugation regular low frequency	decesciamo	decrescere	II	subtraction	decesciuto
not similar	deloviamo				
II conjugation irregular high frequency	diango	piangere	II	substitution	dianto
III conjugation regular low frequency	digneriamo	digerire	III	addition	dignerito
I conjugation low frequency	diguniamo	digiunare	I	subtraction	digunato
III conjugation regular high frequency	diormo	dormire	III	addition	diormito
II conjugation regular high frequency	dresciamo	crescere	II	substitution	dresciuto
II conjugation irregular low frequency	dresisto	desistere	II	addition	dresistito

I conjugation high frequency	duliamo	durare	I	substitution	dulato
I conjugation low frequency	ebbozziamo	abbozzare	I	substitution	ebbozzato
not similar	elboriamo				
I conjugation low frequency	elerviamo	elevare	I	addition	elervato
II conjugation irregular high frequency	elsistiamo	esistere	II	addition	elsistito
I conjugation high frequency	ervitiamo	evitare	I	addition	ervitato
II conjugation irregular low frequency	ervodiamo	erodere	II	addition	ervoso
not similar	escariamo				
II conjugation irregular high frequency	espramiamo	esprimere	II	substitution	esprasso
I conjugation low frequency	essillo	assillare	I	substitution	essillato
II conjugation irregular low frequency	evanciamo	evincere	II	substitution	evanto
II conjugation irregular low frequency	eviolviamo	evolvere	II	addition	evioluto
III conjugation regular high frequency	evvertiamo	avvertire	III	substitution	evvertito
similar I-II conjugation	gebiamo	gelare/gemere	I-II	substitution	
similar I-III conjugation	impaltiamo	impastare/ impartire	I-III	substitution	
II conjugation irregular high frequency	inistiamo	insistere	II	subtraction	inistito
similar I-III conjugation	inquiviamo	inquinare/ inquisire	I-III	substitution	
III conjugation regular high frequency	ippediamo	impedire	III	substitution	ippedito
III conjugation regular low frequency	issento	dissentire	III	subtraction	issentito
II conjugation regular low frequency	itesso	intessere	II	subtraction	itessuto

I conjugation low frequency	naseiamo	nauseare	I	subtraction	naseato
I conjugation high frequency	nelghiamo	negare	I	addition	nelgato
not similar	nerongo				
II conjugation regular high frequency	niceviamo	ricevere	II	substitution	nicevuto
II conjugation irregular high frequency	noscondo	nascondere	II	substitution	noscosto
II conjugation regular low frequency	nueciamo	nuocere	II	substitution	nueciuto
III conjugation regular high frequency	nurriamo	nutrire	III	substitution	nurrito
III conjugation regular low frequency	nusseguo	susseguire	III	substitution	nusseguito
II conjugation irregular low frequency	nussistiamo	sussistere	II	substitution	nussistito
I conjugation high frequency	offidiamo	affidare	I	substitution	offidato
II conjugation irregular low frequency	ompiango	compiangere	II	subtraction	ompianto
II conjugation irregular high frequency	oncludiamo	concludere	II	subtraction	oncluso
I conjugation high frequency	oranizziamo	organizzare	I	subtraction	oranizzato
II conjugation regular high frequency	ossediamo	possedere	II	subtraction	osseduto
II conjugation regular high frequency	ottaniamo	ottenere	II	substitution	ottanuto
III conjugation regular low frequency	paudiamo	plaudire	III	subtraction	paudito
I conjugation high frequency	pecisiamo	precisare	I	subtraction	pecisato
II conjugation irregular low frequency	pecludiamo	precludere	II	subtraction	pecluso
II conjugation irregular low frequency	peristiamo	persistere	II	subtraction	peristito
III conjugation regular low frequency	pesagiamo	presagire	III	subtraction	pesagito

II conjugation irregular high frequency	petendiamo	pretendere	II	subtraction	peteso
I conjugation low frequency	pezoliamo	penzolare	I	subtraction	pezolato
II conjugation regular high frequency	pialciamo	piacere	II	addition	pialciuto
II conjugation irregular high frequency	pivediamo	rivedere	II	substitution	pivisto
III conjugation regular high frequency	plartiamo	partire	III	addition	plartito
II conjugation irregular high frequency	plercorro	percorrere	II	addition	plercorso
not similar	podiviamo				
II conjugation irregular low frequency	poesisto	coesistere	II	substitution	poesistito
III conjugation regular low frequency	porbiamo	sorbire	III	substitution	porbito
I conjugation low frequency	posperiamo	prosperare	I	subtraction	posperato
II conjugation regular low frequency	pottaciamo	sottacere	II	substitution	pottaciuto
I conjugation high frequency	povochiamo	provocare	I	subtraction	povocato
II conjugation regular low frequency	prasciamo	pascere	II	addition	prasciuto
not similar	predegliamo				
III conjugation regular high frequency	prelferiamo	preferire	III	addition	prelferito
II conjugation regular high frequency	prescedo	precedere	II	addition	presceduto
II conjugation regular high frequency	presmo	premere	II	addition	presmuto
I conjugation low frequency	prizzico	pizzicare	I	addition	prizzicato
I conjugation high frequency	pruntiamo	puntare	I	addition	pruntato
III conjugation regular high frequency	puggeriamo	suggerire	III	substitution	puggerito
not similar	ralbidiamo				
not similar	ramosto				

II conjugation irregular high frequency	rensistiamo	resistere	II	addition	rensistito
II conjugation regular low frequency	renvoliamo	benvolere	II	substitution	renvoluto
I conjugation high frequency	resteggio	festeggiare	I	substitution	resteggiato
similar I-II conjugation	riarfiamo	riarmare/ riardere	I-II	substitution	
II conjugation regular low frequency	ricesciamo	ricrescere	II	subtraction	ricesciuto
III conjugation regular high frequency	riepio	riempire	III	subtraction	riepito
similar I-III conjugation	rifiviamo	rifilare/rifinire	I-III	substitution	
similar I-III conjugation	riforviamo	riformare/ rifornire	I-III	substitution	
III conjugation regular low frequency	rilfuggo	rifuggire	III	addition	rilfuggito
I conjugation low frequency	rimbiocco	rimboccare	I	addition	rimbioccato
II conjugation irregular low frequency	rimergo	riemergere	II	subtraction	rimerso
II conjugation irregular high frequency	riviolgo	rivolgere	II	addition	riviolto
I conjugation low frequency	roggiriamo	raggirare	I	substitution	roggirato
II conjugation regular high frequency	rombatto	combattere	II	substitution	rombattuto
III conjugation regular low frequency	rompatiamo	compatire	III	substitution	rompatito
I conjugation high frequency	ronfermiamo	confermare	I	substitution	ronfermato
III conjugation regular high frequency	ronsentiamo	consentire	III	substitution	rolpito
II conjugation irregular low frequency	rontorciamo	contorcere	II	substitution	rontorto
II conjugation regular low frequency	sfiotto	sfottere	II	addition	sfiottuto
similar I-II conjugation	spiatiamo	spianare/ spiacere	I-II	substitution	

II conjugation regular high frequency	tatteniamo	trattenere	II	subtraction	tattenuto
similar I-II conjugation	tugliamo	tagliare/togliere	I-II	substitution	
similar I-II conjugation	zaciamo	baciare/tacere	I-II	substitution	

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