# Attention, Awareness and Noticing in Language Learning: An Extension of Williams (2005)

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# 1. Abstract

There is a long-standing interest in investigating the role of implicit and explicit learning in the area of second language acquisition (cf. Ellis 1994; DeKeyser, 2003; Hulstijn & Ellis, 2005; Williams, 2005; Rebuschat & Williams, 2012, inter alia). This interest was kindled by Krashen's *acquisition-learning divide* (cf. Krashen 1981, 1994). The question of differences between implicit and explicit learning and their interaction and the role they play in second language (L2) learning is "fundamental in that it determines how one believes second language are learned and whether there is any role of instruction" (Ellis, 2011, p. 35).

While many studies have focused on incidental learning especially in the domain of L2 vocabulary acquisition (see Hulstijn, 2003, for a review) without attempts to account for the implicitness of acquired knowledge as well as on the effectiveness of instruction intervention (cf. Norris & Ortega 2009; Spada & Tomita 2010), there is still relatively little work on the nature of implicit learning mechanisms and knowledge in L2 acquisition (cf. Rebuschat, 2013a).

In the L2 acquisition context, definitions and characterizations of implicit learning typically involve descriptions such as "learning without awareness", "unaware learning" or "incidental learning". Hence, one of the key challenges has been on how to assess whether a learner was aware or not of the statistical regularities in the stimuli s/he was exposed to. This is especially true for studies with the goal to determine, whether language can be acquired without awareness and the extent to which language can be learned without awareness or, conversely, whether and to which degree conscious awareness is required and may facilitate language acquisition.

A great deal of research on implicit L2 learning employing artificial grammar learning or serial reaction time paradigms has primarily been focused on the abstraction of form-form regularities without considering meaning or function (see Hulstijn, 2003, for a review). However, for the acquisition of natural language learning it is of great importance to also investigate implicit learning of form-

meaning alignments, which has been addressed in more recent research (see Williams 2009 for an overview).

In a much-cited study, Williams (2005) attempted to clarify the role of awareness in L2 acquisition. He investigated whether a form-meaning alignment (determiner-animacy mapping) can be learned when the subjects' attention is directed to a different form-meaning alignment (determiner-distance mapping). The results showed a significant learning effect even in the subjects assumed to be unaware of the determiner-animacy alignment.

However, a number of extensions of this study (Leung & Williams, 2006; Hama & Leow, 2010; Faretta-Stutenberg & Morgan-Short, 2011; Rebuschat et al., 2013, 2015) showed mixed results. Rebuschat et al. (2013) assumed these differences to be the result of both inaccurate assessments of awareness and the learning effect being weaker than originally assumed.

This thesis contributes to the ongoing debate on implicit statistical language learning of form-meaning alignments through the further refinement of methods for the identification of learning without awareness. Combining new methods with design components described in prior research, the goal of this study is to minimize the chance of attributing learning without awareness effects to contexts in which some degree of awareness must be assumed to be present.

# 2. Theoretical Background

## 2.1. Implicit Learning

*Implicit learning* is a term coined by Reber (1967) to describe a learning process by which subjects respond to statistical regularities in a stimulus array and was first used in his studies on artificial grammar learning. In those experiments Reber (1967) exposed the subjects to abstract letter strings and asked them to memorize them. The arrangement of those letter strings (e.g. “TPTS, VXXVPS and TPTXXVS”) was determined by a finite-state grammar. After the training phase the subjects were told that the strings were generated according to a complex rule system and were asked to judge the grammaticality of new examples of which only half followed the original grammar. Reber (1967) found that subjects judged 79% of all letter sequences correctly and concluded that memorization of the strings was sufficient for subjects to learn parts of the underlying grammar. However, when asked to verbalize the underlying rule system, the subjects were unable to do so. Due to the fact that the subjects were not informed of the rules or the test on the subjects rule knowledge and due to their inability to verbalize the rules, Reber (1967) concluded that they were able to acquire knowledge without intending to do so and without awareness of the acquired knowledge, coining the term *implicit learning* to differentiate this process from *explicit learning*, which describes a learning process in which subjects deliberately form and test hypotheses about the stimulus domain.

In the past decades implicit learning has been investigated in a wide range of experimental paradigms, including artificial grammar learning experiments, sequence learning experiments and experiments on the control of complex systems (see chapter 3). These experiments have resulted in a consensus on some of the characteristics of implicit learning (see Berry & Dienes, 1993 for a review). However, a great number of questions, as, for example, the question of how the implicit knowledge is represented and what level of awareness is necessary for learning to take place, are still contested (see Berry & Dienes, 1993; Cleeremans et al., 1998; Dienes & Berry, 1997).

A common result of experiments investigating acquisition of implicit knowledge is that subjects tend to rapidly learn about a rather complex stimulus environment without intending to do so (see Dienes, Altmann, Gao, & Goode, 1995; Dienes & Scott, 2005; Tunney & Shanks, 2003). The acquired knowledge is generally situated at a subconscious, intuitive level, meaning that subjects, even though they may have developed some explicit metaknowledge, allowing them to make informed judgments about the correctness of the produced output, remain unable to express the acquired knowledge verbally (e.g. Dienes & Scott, 2005; Rebuschat, 2008; Rebuschat & Williams, 2006, 2012).

Berry & Dienes (1993) provided a preliminary characterization of implicit learning that captured the current consensus. In their work, four major traits are associated with implicit learning. First, they identified *transfer specificity* as a central aspect and claim that nearly all studies of implicit learning showed very low rates of transfer of knowledge to free recall. This is shown in the subject's inability to verbalize or transfer the knowledge they acquired. However, this only serves as an incomplete and insensitive measure, as lack of transfer can also reflect the problem of subjects having to retrieve large amounts of low confidence knowledge. This also causes problems when using forced choice tests for assessing acquired knowledge, as it is unclear, whether low confidence explicit knowledge or implicit knowledge is retrieved. To address this issue researchers have recently started to employ subjective confidence and source measurements (see Rebuschat 2013b for review).

The transfer specificity also showed in the limited transfer to tasks with the same underlying structure. Both Cleeremans (1998) and Berry & Dienes (1993) claim that most studies showed no or only limited transfer of learning, while only a few showed equivalent performance. The second aspect they specify is the association of implicit learning to incidental learning conditions in contrast to deliberate hypothesis testing. Studies on this matter have shown that subjects that approach complex implicit learning tasks passively, without trying to figure out an underlying rule system, seem to yield the same or better results compared to subjects who try to figure out the underlying rule system explicitly. Thirdly they highlighted the intuitive nature of the acquired knowledge, which is described above. The final characteristic they attribute implicit learning with is *robustness*. Several studies have shown that implicit knowledge is more robust in face of time, secondary tasks (e.g. Allen & Reber, 1980; Orrell et al., 2007) and neurological disorder (e.g. Knowlton, Ramus, & Squire, 1992; Smith, 2001; Schuchard & Thompson, 2014), suggesting that implicit knowledge is qualitatively different from explicitly acquired knowledge and can be associated with different properties of storage and retrieval.

The field of Second Language Acquisition (SLA) has been interested in the topic of implicit and explicit learning for three decades (Andringa & Rebuschat, 2015; Williams & Rebuschat, 2015; Sanz & Leow, 2011; Hulstijn & R. Ellis, 2005; Ellis, 1994; Krashen 1981, 1994). This interest was first kindled by Krashen's introduction of his *language acquisition-learning* divide and the *monitor hypothesis* (Krashen, 1977; 1979; 1981; 1994 and elsewhere). He conceived language acquisition as an incidental process that results in tacit linguistic knowledge and language learning an intentional process which results in conscious linguistic and metalinguistic knowledge. In his *Monitor Theory* he claimed the implicit knowledge to be solely responsible for language production and comprehension. Explicit knowledge, on the other hand, is seen as a separate entity in the brain and with no interface to implicit knowledge. It is only responsible for "monitoring" the output created by the implicit knowledge and correcting mistakes. Therefore, it cannot contribute to the implicit knowledge and thus cannot improve the language fluency, as it can only be applied to the language production if the subject has a concern for correctness, knowledge of the rules and sufficient time to employ the knowledge (Krashen, 1982). This led Krashen the opinion that language pedagogy should focus on allowing students to acquire language implicitly, as opposed to traditional explicit language learning. A number of researchers criticized this and argued that there is no distinction between explicit and implicit language learning (McLaughlin 1978; 1987; Gregg 1984; Odlin 1986; Gass & Selinker 2001) or that language learning is located on a continuum between those two extremes (Laufer 1997) (see N. Ellis, 2011, for review).

Despite the controversy, due to the profound discussion, Krashen's hypotheses are also responsible for the increased interest in the role of implicit and explicit learning and knowledge in the SLA research. Ellis (2005, p. 143) summarized the situation as follows:

> "There is broad consensus that the acquisition of an L2 entails the development of implicit knowledge. However, there is no consensus on how this is achieved; nor is there consensus on the role played by explicit knowledge."

In the past decades the relation of awareness and implicit learning has been a major area of empirical research and theoretical discussion. Researchers have enquired into the possibility of learning without awareness (e.g. Godfroid & Winke, 2015; Hama & Leow, 2010; Leow, 1997, 2000, 2014; Leow & Hama, 2013; Leung & Williams, 2011; Paciorek & Williams, 2015; Schmidt, 1990, 1995, 2001; Williams, 2005, 2009), into possibilities of measuring awareness both at the time of encoding (e.g. Godfroid & Schmidtke, 2013; Leow, 1997; Leow, Grey, Marijuan, & Moorman, 2014) and retrospective, i.e. the awareness of what has been learned (e.g. R. Ellis, 2005; Grey, Williams, & Rebuschat, 2014; Hamrick & Rebuschat, 2012; Rebuschat, 2013; Rebuschat, Hamrick, Sachs, Riestenberg, & Ziegler, in press), and into the existence of an implicit explicit interface that allows explicit knowledge in form of taught pedagogical rules to promote development of implicit knowledge (Ellis, R., 2015).

While the experiments using Artificial Grammar Learning (AGL) conducted by Reber and colleges (1967, 1969, 1976; Reber & Allan, 1978; Reber & Lewis, 1977; Reber & Millward, 1968, 1971) heave led to the artificial grammar learning paradigm (see chapter 3.1), their studies were not the first studies that employed finite-state grammars to investigate aspects of human cognition. Reber (1967) himself pointed out Gibson and Gibson's (1955) study on perceptual learning and Miller's (1958) study of free recall. Also using artificial language systems to investigate different aspects of language acquisition, they and several other researchers developed a different strand of research. (e.g. Braine, 1963, 1966; Moeser & Bregman, 1972; Segal & Halwes, 1965, 1966; Smith, 1966). This emerged as a major line of inquiry within developmental psychology and cognitive science. This strand developed into *statistical learning* (Saffran, Aslin, & Newport, 1996; Saffran, Newport, & Aslin, 1996) and has remained very productive to this day (e.g. Misyak, Goldstein, & Christiansen, 2012; Gómez, 2007; Saffran, 2003; see Frost et al., 2015 for a review).

Recently a number of researchers have pointed out that both statistical learning research and implicit learning research focus on the same phenomena from different perspectives and should be unified (Perruchet & Pacton, 2006; Conway & Christiansen, 2006). Both approaches are interested in the acquisition of information from stimulus arrays, which are traditionally generated using artificial grammar systems and they share the same general experiment structure: Subjects are exposed to a stimulus array and then tested on whether and to what degree they acquired knowledge on the rules governing the artificial grammar system used to generate it. Given these and other similarities, Perruchet & Pacton (2006) suggested that implicit and statistical learning represent two approaches to a single phenomenon. Conway & Christiansen (2006) go as far as combining the two by suggesting the name: *implicit statistical learning* (see also Onnis, Destrebecqz, Christiansen, Chater, & Cleeremans, in press; Perruchet & Poulin-Charronat, in press; Walk & Conway, in press).

## 2.2. Statistical Learning

The flow of information in the sensory world is rich in statistical structure. Any kind of sensory stimulation abounds in frequent associations and patterns over basic units. The ability of the human brain to compute statistical information based on those basic units is considered *statistical learning*. Statistical structures can take a multitude of forms, for example the frequency of co-occurrence, the frequency of individual units or the transitional probability of one unit to another. Statistical learning research focuses on finding the commonalities of this mechanism across different domains in order to unify them into a unitary system (see Gómez 2007, Frost et al. 2015).

In statistical language learning research this involves computations based on basic units or patterns of sounds, syllables, syntactic categories etc. Much research in statistical language learning focuses on infant or child language acquisition (e.g. Saffran et al., 1996; Aslin, Saffran, & Newport, 1998; Gomez & Gerken, 1999; Kuhl, 2004; Gerken, 2006; Thiessen, 2007; Diessel, 2011; Slone & Johnson, 2015); however, AGL-Studies with adult subjects are also common (Saffran et al. 1997; Gomez, 2002; Newport & Aslin, 2004; Perruchet et al., 2004; Gomez & Maye, 2005).

In a seminal paper, Saffran et al. (1996; see also Aslin, Saffran, & Newport, 1998) showed that 8 month old humans could track transitional probabilities in sequences of syllables to discover word boundaries. In order to test this they exposed infants to a continuous stream of four randomly ordered three-syllable words (e.g. tupiro, golatu). The different syllables occurred with the same frequency and nothing but the lower transitional probabilities for syllables spanning words compared to syllables within words served as cue for word boundaries. For example, in the phrase **naugh-ty-pu-ppy**, the syllable **naugh** is more likely to predict the syllable **ty**, than for **ty** to predict **pu**. Therefore, the transitional probability for **naugh-ty** is higher than for **ty-pu**. The children in Saffran et al.'s studies showed the ability to compute those probabilities and use them to identify word boundaries in speech. This research showed for the first time that very young children are able to track complex sequential structure using statistical information. It also raised a number of questions, the most important being whether statistical learning can be found for other structures than word segmentation as well. This was explored in a great number of studies building on the work of Saffran and colleagues, and recent studies (see Frost et al., 2015 for a review) show that statistical learning extends into a wide range of other linguistic domains (see Gómez 2007 for a comprehensive list).

Despite the large amount of similarities I outlined above, implicit and statistical learning research has several important differences. For example, the careful manipulation of statistical information in the input, which is a key method in statistical learning research, is usually completely absent in implicit learning research. Both areas of study also focus on different aspects of the same phenomena. Statistical learning is concerned with how humans acquire linguistic information, while implicit learning research is more concerned with information acquisition in general. Therefore, statistical learning researchers tend to use artificial systems with a stronger resemblance to natural language (phrase-structure grammars instead of finite state systems, and pseudo words instead of letter sequences). Due to the different focus statistical learning researches focus less on the question whether the acquisition of knowledge is conscious or unconscious. Designs for studies on implicit learning usually employ a number of methods such as subjective measurements or think aloud protocols to measure awareness (see Rebuschat 2013 for a review). While this is easy to explain for infant studies, in experiments that employ adult subjects, basic measures of awareness could be administered, as usually a lack of awareness is assumed but not assessed (see Aslin, Saffran, & Newport, 1999, Dell, Reed, Adams, & Meyer, 2000; Warker & Dell, 2006). Thus there is still no conclusive evidence that statistical learning generally results in unconscious knowledge.

## 2.3. Awareness

Even though there has been considerable interest in the topic of implicit and explicit learning in the SLA research, the contribution of implicit learning to the SLA remains unclear. A major reason for this is the difficulty to differentiate between implicit and explicit learning (Williams, 2009). The most commonly used criterion to determine the type of knowledge is the level of awareness. However, in the different studies a multitude of definitions for awareness has been employed, which makes it hard to adjudicate between them. Implicit knowledge is unconscious knowledge which subjects cannot verbalize and are not aware of. They might, however, have meta-knowledge which allows them make judgments on the accuracy of their knowledge. Explicit is conscious knowledge and subjects will be aware of having it, but they might still be unable to verbalize it and they might also lack the meta-knowledge to judge their accuracy. Despite these difficulties there are a number of ways to assess the type of knowledge which will be discussed later in this thesis.

Another area of great interest is the role awareness plays in implicit learning and whether implicit learning is possible without awareness, or, if not, which level of awareness is necessary to accommodate it. While there have been a great number of studies showing signs for perceptual processing in absence of conscious awareness in normal subjects (e.g. Balota, 1983; Fowler, Wolford, Slade, & Tassinary, 1981; Marcel, 1980; 1983) and as well in brain-damaged patients (Berry & Dienes 1993, Chapter 6), critics have argued that due to methodological difficulties and inadequacies in establishing the level of awareness many of those findings remain unacceptable.

There are two different levels of unawareness that are generally distinguished in literature, the *objective* and the *subjective threshold* (Cheesman & Merikle, 1984). The *objective threshold* is the level of awareness, at which subjects respond to tests of awareness at chance level and therefore has no knowledge of the stimuli that has been presented. The *subjective threshold* is reached once subjects claim to be unaware of any stimuli input and thus have not yet developed any metaknowledge about the knowledge they acquired from the input (Dienes & Berry, 1997).

In their study Cheesman and Merikle (1984) briefly presented subjects with one of four stimuli, asked them to report which stimulus was displayed and had them estimate their performance after each block of 48 trials. In addition they systematically decreased the time each stimulus was displayed, which lead to a decrease in performance. However, even when considering themselves to be guessing (subjective threshold) subjects still performed significantly above chance level. Only after further reduction of the exposure time the objective threshold was reached.

Several studies (e.g. Merikle, 1990; 1992; Krosnick, Betz, Jussim, & Lynn, 1992, Kihlstrom, 2004; Merikle & Daneman, 1998; Merikle et al., 2001) have shown that there are qualitative differences between perceptual processing below as compared to above the subjective threshold, which show in above chance level guesses and by reliable priming if the exposure to the stimuli was above the objective and below the subjective threshold. Some findings (Krosnick, Betz, Jussim, & Lynn, 1992) even imply that those stimuli can produce long-lasting affective changes towards the previously neutral stimuli. Thus the subjective threshold provides a useful divide between the conscious and unconscious.

Beyond the two levels of the unconscious two levels of awareness can be distinguished. The first is awareness at the level of *noticing* and is defined by the „conscious registration of an event" (Schmidt, 1995, p. 29). This would be, for example, noticing the morpheme '-ed' in words like talked, asked and solved in a text. The second level is awareness at the level of *understanding*, which refers to the „recognition of a general principle, rule or pattern" (Schmidt, 1995, p. 29). This requires the subject to recognize that the morpheme '-ed' indicates past tense and that there is a productive rule (verb stem and -ed produces the regular past tense of a verb). In several studies (1990, 1993, 1994, 1995, 2001) Schmidt found that awareness at the level of noticing serves as „the necessary and sufficient condition for the conversion of input into intake" (Schmidt, 1993, p. 209). Schmidt's theories resulted in a number of empirical studies (e.g. Leow, 1997, 1998, 2000; Rosa & Leow, 2004; Rosa & O'Neill, 1999) exploring this theory and supporting it.

In Leow (2000) L2 learners of Spanish were exposed to morphological forms (irregular 3rd person singular and plural preterit forms of stem-changing –ir verbs) using an ingenious crossword-puzzle task and subsequently written production and recognition tasks were used to test whether learning took place. Using think-aloud protocols (see chapter 3.1) they classified the subjects as either aware or unaware. If they mentioned the targeted forms or any thoughts on the underlying rule system they would be classified as aware. Contrary to the earlier studies they found that only subjects classified as aware showed improvement during the task, while subjects classified as unaware showed no signs of improvement at all. Based on these findings Leow (2000) suggested that awareness is crucial to L2 acquisition by making input available for subsequent processing. This observation has received support from a number of studies using the same methodology (Leow, 1997, 1998; Rosa & Ó'Neill, 1999; Rosa & Leow, 2004) and a number of other studies showed that higher levels of awareness are associated with higher levels of learning (Hamrick & Rebuschat, 2012; Rosa & Leow, 1994; Rosa & O'Neill, 1999; Rebuschat & Williams, 2012; Sachs & Suh, 2007). The important role of attention and awareness in learning processes is generally accepted (see Leow & Bowles, 2005; Robinson, 2003; Schmidt, 2001, for reviews), however, the debate on which level of awareness or unawareness is the bottom-line for acquisition to take place, remains unresolved. In a widely-cited study, Williams (2004, 2005) examined the acquisition of form-meaning mappings at low levels of awareness and found a significant learning effect. While the study was criticized on methodological grounds a number of follow-up studies were unable to resolve the controversy surrounding this topic (Hama and Leow, 2010; Faretta-Stutenberg & Morgan-Short, 2011; Rebuschat et al., 2013, 2015).

# 3. Common Methodology of Implicit Learning Research

With the measurement of awareness being a major concern in the study of L2 acquisition, a number of methods to assess the level of awareness have been developed by different researchers. Out of the number of methods two central paradigms emerged: One focuses on extracting reliable cues for the level of awareness from different types of subjective reports, such as retrospective interviews, think aloud protocols or ratings on different kinds of scales, and the other uses series of reaction tests in which the decrease of reaction time during a series of tests serves as measure for learning. In both paradigms a combination of indirect and direct tests is employed to identify differences and use those to draw conclusions on the type of knowledge the subjects acquired, as it is generally assumed that indirect tests target implicit knowledge and direct tests target a combination of explicit and implicit knowledge.

## 3.1. Grammar Learning Paradigm

In Rebuschat (2013b) a comprehensive discussion of methods following this first paradigm is provided. The first important method is retrospective interviews. It is one of the most common procedures for measuring the type of knowledge the subjects acquired during the experiment. Generally, during the debriefing, the subjects are asked to verbalize any rules or patterns they noticed during the experiment (e.g. Dienes, Broadbent, & Berry, 1991; Lewicki, Hill, & Bizot, 1988; Reber, 1967; see Ericsson & Simon, 1980; Nisbett & Wilson, 1977; Payne, 1994, for reviews). If the subjects display an effect of learning during the experimental task (e.g. above-chance performance on a grammaticality judgment task) but remain unable to verbalize that knowledge, it is considered unconscious. A great number of studies (e.g. Berry& Broadbent, 1984; Broadbent, 1977; Green & Hecht, 1992; Rebuschat &Williams, 2006, 2009, 2012a; Williams, 2005) have shown evidence for learning without awareness, if the inability to verbalize the knowledge is used as criterion for unawareness.

However, this has been criticized for a number of reasons (for an overview, see Shanks & St. John, 1994). First, there is evidence that the inability to verbalize the knowledge is in part the result of subjects lacking the skill to create rules from abstract knowledge and will be able to do so, after this skill is trained (Dienes & Fahey, 1995; McGeorge & Burton, 1989; Stanley, Mathews, Buss & Kotler-Cope, 1989). This is also supported by Berry and Dienes (1993), who observed that having to retrieve low confidence knowledge might very well cause the same inability to verbalize the knowledge. This makes it difficult to determine whether low confidence explicit knowledge or implicit knowledge is the cause. Furthermore, there is evidence for above chance performance on artificial grammar learning tasks even if the subject has only knowledge of fragments or chunks (Perruchet & Pacteau, 1990; Servan-Schreiber & Anderson, 1990). Some of those issues have been addressed in recent years by using different kinds of verbal reports, as for example think aloud protocols, for which subjects are asked to verbalize their thoughts while doing the tasks. These protocols can take a number of forms, from a non-metalinguistic type (subject focuses on the task and only verbalizes his thoughts) to a metalinguistic type (subject provides linguistic reasoning on the task) or even to a metacognitive type (subject provides additional information on his thoughts, reasoning processes). A number of studies support the value of this kind of measurement for operationalizing awareness (e.g. Bowles, 2003 , 2004 , 2008; Leow, 1997 , 1998a , 1998b , 2000 , 2001; Leow & Morgan-Short, 2004; Rosa & Leow, 2004a , 2004b ; Rosa & O'Neill, 1999; Rott, 2007; Sachs & Suh, 2007).

Another method Rebuschat (2013b) looks at is the use of subjective measures. In their research on subliminal perception, Cheesman and Merikle (1984, 1986) have found that *subjective unawareness* (see chapter 2.3) serves as a productive threshold to distinguish between the conscious and unconscious. This was taken up by several implicit learning researchers (Dienes, 2004, 2008, 2012; Dienes, Altmann, Kwan, & Goode, 1995; Dienes & Berry, 1997; Dienes & Perner, 1999; Dienes & Scott, 2005), who advocate the use of the *subjective unawareness* for implicit learning research as well. Dienes et al. (2005) explained the subjective unawareness with the lack of metaknowledge and suggested that subjects might lack metaknowledge in two ways. The first is that the subjects believe that they are guessing and thus don't have any metaknowledge at all. This they called guessing criterion. Secondly subjects might possess partial or wrong metaknowledge. This leads to their confidence being unrelated to their accuracy. This criterion was originally described by Chan (1992) and named zero correlation criterion by Dienes et al. (1995). A number of studies have shown that subjects are able to develop unconscious knowledge by these criteria (e.g. Channon et al., 2002; Dienes et al., 1995; Dienes & Longuet Higgins, 2004).

However, since the measures are subjective, they remain susceptible to criticism. The problem with subjective measurements is that, since the participants set their own criteria for reporting knowledge, they may systematically claim to be guessing, when, in fact, they possess a small degree of awareness (Reingold & Toth, 1996; see Dienes, 2004, 2008, for discussion). Kurimoto et al. (2001) proposed to solve the issue with response bias by combining the confidence ratings with a signal detection analysis, a psychological method to estimate the strength of response data relative to noise and subject willingness to respond in particular ways (Green & Swets, 1966). The signal detection theory measure of sensitivity can be used to normalize the confidence ratings to serve as a bias-free measure of awareness (see Wickens, 2002, for an introduction).

A further issue pointed out by a number of studies (see Dienes, 2008, 2012; Dienes & Perner, 1999; Seth et al., 2008) is the fact that confidence ratings are only able to capture *judgment knowledge*, but not *structural knowledge*. Based on Rosenthal's (2005) Higher-Order Thought theory Dienes proposed a convincing explanation for the problem that in the case of natural language acquisition accuracy and confidence is highly correlated, even though the linguistic knowledge is implicit. Dienes (2008, 2012) suggested that in case of language learning tasks subjects learn *structural (linguistic) knowledge* which can consist of fragments, whole exemplars or incomplete rules. When asked to judge the grammaticality of phrases the subjects then use this subconscious knowledge to construct the *judgment knowledge*, which then allows them to assess those items.

This *judgment knowledge* can be both conscious and unconscious Dienes and Scott (2005). The guessing and the zero correlation criteria measure the conscious or unconscious status of judgment knowledge, not structural knowledge. If the judgment knowledge is conscious, the phenomenology is that of intuition, as it is the case for first language knowledge, in which structural knowledge is unconscious while judgment knowledge is conscious. On the other hand, if judgment knowledge is unconscious, the phenomenology is that of guessing. In both cases the structural knowledge used for language production is unconscious. Therefore, Dienes and Scott suggest using source attributions, in which subjects are asked to provide the basis of their judgements as well (cf. Rebuschat, 2008, Experiment 3). As Dienes & Scott (2005) suggest, the proposed sources could be guessing, intuition, conscious rules or memory.

The last method Rebuschat mentions is the combination of indirect and direct tests. This method was first used in Reingold and Merikle (1988) in which the authors tested the relative sensitivity of tasks to direct and indirect indexes of perception. The contrastive use of direct and indirect tests was then taken up by several authors as it is considered a more exhaustive way to distinguish implicit and explicit knowledge than retrospective interviews (e.g. Jiménez, Méndez, & Cleeremans, 1996; Reed & Johnson, 1994; Willingham, Nissen & Bullemer, 1989). In direct tests subjects are instructed to make full use of their knowledge. Generally the subjects are told that an underlying rule system exists and asked to figure it out it (St. John & Shanks, 1997). For indirect tests the subjects are not told about the rule system and, ideally, the task should be designed in a way that the subjects do not even realize they are being tested. If the indirect test indicates a learning effect while the direct test does not, the knowledge is assumed to be unconscious. This type of test has been employed in a number of studies on artificial grammar learning (e.g. Dulany et al., 1984; Perruchet & Pacteau, 1990), sequence learning (e.g. Cleeremans & McClelland, 1991; Jiménez et al., 1996; Perruchet & Amorim, 1992), and SLA research (e.g. R. Ellis, 2005). Despite mixed results, several studies have shown that exposure can lead to unconscious knowledge, using this as criterion (e.g. Jiménez et al., 1996; Ellis et al., 2009; R. Ellis, 2005;).

While this type of tests is generally accepted to be a more sensitive measure of awareness than retrospective verbal reports (Reingold & Merikle, 1990; St. John & Shanks, 1997), results of this type of task cannot be used as conclusive evidence against learning without awareness, as direct tests tend to lack exclusivity. This means that even though they are supposed to only measure conscious knowledge, they often capture unconscious knowledge as well (Reingold and Merikle, 1988, 1990). For example, grammaticality judgments might reflect both the contributions of conscious and unconscious knowledge, and it is not clear that the addition of time pressure to the task will resolve the issue, because explicit knowledge can be deployed rapidly given sufficient practice (Williams, 2009). Thus, any approach based on the contrastive use of direct and indirect tests runs the risk of underestimating the influence of unconscious knowledge (Merikle, Smilek, & Eastwood, 2001).

A recent trend in this research strand is to combine different measures of awareness in order to counteract the different issues caused by the insensitive methods. A few researchers have been using this method in their studies, and Rebuschat (2013b) explicitly asks researchers to combine different measures for greater clarity.

## 3.2. Serial Reaction Time Paradigm

The second main paradigmatic method is the use of *serial reaction time* (SRT) tasks. In a SRT task, subjects are asked to react to input stimuli as fast as possible. Usually the sequence of the input stimuli is governed by an underlying rule system. The decrease of reaction time over time compared to a randomized baseline serves as measure for implicit learning. As the exposure time is very low, usually less than one second, and the underlying rule system is generally rather complex, any knowledge gained is normally considered implicit. Two variants of this paradigm are distinguished. In the deterministic variant the sequence follows an unchanging pattern, while the probabilistic variant only follows the pattern to a certain degree (e.g. the pattern is used in 90% of the time, but sometimes a stimuli is exchanged with noise). The advantage of the probabilistic variant is that it allows for on-line monitoring. This means that even during the trial conclusions can be drawn by comparing predictable items with items that do not follow the underlying pattern.

In order to distract the subject's awareness from the underlying pattern many studies choose to employ a secondary task. One of the most popular secondary tasks is a tone counting task impaired (Cohen, Ivry, & Keele, 1990; Curran & Keele, 1993; Frensch, Lin, & Buchner, 1998; Hsiao & Reber, 2001; Schvaneveldt & Gomez, 1998; Shanks & Channon, 2002; Stadler, 1995). For this a number of high and low pitched tones are emitted in between the tasks and subjects are required to keep a running count of the number of one type of tone and record it at the end of each testing block (see Hsiao & Reber, 1998; Shanks, 2003, for reviews). This type of secondary task has been recognized as a suboptimal, as it has been shown that it is difficult to attribute the impairing effect this task has on the implicit learning to its demands on attentional resources or if some non-attentional factor is responsible for this impairment (see Heuer & Schmidtke, 1996; Hsiao & Reber, 2001; Shanks, 2003; Stadler, 1995, for extensive discussion of these issues). Another approach was demonstrated by Jimenez & Mendez (1999, 2001). They had four different types of symbols appear at different locations on a screen and required the subjects to click that location. Under single-task conditions the subjects only had to attend to the location of the symbol, but under dual-task conditions they had to keep track of the combined number of appearances of two types of symbols as well. This forced the subjects to make two decisions on each task without introducing an additional stimulus.

The SRT task is used in a number of other fields of study (e.g. sequence and procedure learning) as well, but it is also a very useful tool for implicit language learning research and has been widely used in both statistical learning and implicit language learning studies (Hunt & Aslin, 2001; Buchner et al., 1998; Shanks, 2005; Remilliard, 2003). But on the other hand its application is still limited, as it can only be used to study acquisition of statistical regularities in simple form-form mappings. It is also much more complicated to modify the paradigm to suit the needs of specific studies, so studies using SRT tasks usually do not modify the method itself, but only the content and the subjects used for those tests.

# 4. Prior studies

In light of the mixed results of studies exploring the role of awareness in L2 acquisition, Williams (2005) set out to investigate its role in acquisition of form-meaning alignments using an AGL task. He developed a design which exposed the subjects to novel forms (artificial determiners), while keeping the critical aspects of meaning (animacy) hidden. The subjects were exposed to four new determiners which encoded both distance between the subject of the sentence and the modified object and the animacy of the modified object (see table 1). These artificial determiners were presented in normal English sentences. The subjects were informed that the artificial functioned like normal English determiners, but also encoded distance between subject and object. They were not told that those determiners encode animacy, as this served as a hidden regularity.

| | Near | Far |
|---|---|---|
| Animate | gi | ul |
| Inanimate | ro | ne |

**Table 1**: Artificial Determiners in Williams (2005)

The subjects were given a vocabulary pre-training in which they were given cards which had the determiner on one side (e.g. gi) and the corresponding distance type (e.g. near) on the other side. In order to make the subjects use both determiners the distance type was color coded as well (e.g. near in red would correspond to gi). To pass the pre-training they had to complete a twelve item vocabulary test without errors. After the pre-training the subjects were given a deceptive explanation of the experiment (see Williams, 2005 for exact wording) and asked to listen to several sentences containing the artificial determiner (e.g. The little boy patted *gi* tiger in the zoo.), repeating it exactly aloud, and finally forming a mental image of the situation. During the training phase they were exposed to six sets of 24 trials, consisting of 40 unique determiner-noun pairings which were repeated up to 3 times. After the training phase the subjects had to complete a two-alternative forced-choice task in which they were asked to complete partials sentences by choosing the determiner which felt “more familiar, better, or more appropriate” (Williams, 2005) (e.g. partial sentence: The lady spent many hours sewing…; answer 1: gi

Cushions; answer 2: ro cushions). Once they completed this task, they were asked to provide insight into the criteria they used for their choices and those who made any references to living or non-living as categories were considered aware of the form-meaning connection. After this they were told that the usage of *ro/gi* or *ne/ul* is controlled by a grammatical rule and asked to find that rule. Then they were subjected to a second round of testing, which included some trained items, and interviewed again.

Williams (2005) found that even the 33 subjects who he judged unaware of the relevancy of animacy in the determiner usage, performed at 61%* (“*” equals $p < 0,05$) accuracy in the 2AFC task. After the rule discovery task 50% of the subjects remained unaware of the rule but still performed at 58%* accuracy. Based on these results Williams (2005) argued that the subjects were able to learn a form-meaning alignment without having any conscious knowledge of the connection between them and that the abstraction of the unconscious knowledge to rule knowledge is an unconscious process as well.

These results were widely discussed and criticism concerning the method to establish awareness was voiced. When Hama and Leow (2010) extended the original study, they employed think-aloud protocols to capture the awareness at the point of encoding, as opposed to Williams (2005) who measured whether the exposure resulted in conscious or unconscious knowledge. They also used only the auditory modality instead of a mix of auditory and written modality, included a production task and offered all four determiners as options for the forced-choice task. On basis of the think-aloud protocols the subjects were split into three groups: *understanding, noticing*, or *no report*. If some aspect of animacy was mentioned, the verbal report was assigned to the group *noticing*. If the correct rule was mentioned, they were tagged as *understanding* and those who did neither were tagged as *no report*. Based on their data they classified nine subjects as aware and 34 subjects as unaware. Of those further 11 were removed, as they showed awareness of the connection by mentioning alternative strategies for decision not based on animacy. In the remaining 23 unaware subjects, Hama and Leow (2010) could not find any significant sign of learning. The same is true for another extension by Faretta-Stutenberg and Morgan-Short (2011). They used the same methodology (2AFC-test, retrospective verbal reports) as Williams (2005), but also applied the finer graded categories for awareness. They found a very weak, but not statistically significant effect.

Rebuschat et al. (2013, 2015) argued that this difference might stem from using awareness measurements relying on the verbalization of knowledge by the subjects. He claims that both verbal reports and think-aloud protocols are not sensitive enough to disentangle implicit and explicit knowledge, as awareness may be very limited and might not reported, due to being low confidence knowledge. On the other hand, implicit knowledge might influence some decisions, even though awareness has been observed. On basis of this criticism Rebuschat et al. (2013) designed a replication of Williams (2005) in which they employed subjective measures that do not rely on awareness. He asked his subjects to provide not only confidence measures for each task, but also source attributions as proposed by Dienes and Scott (2005). Rebuschat et al. (2013) also added a trained control group. This group was exposed to training items to which the four different determiners were assigned randomly and not based on the animacy rule. Furthermore, they added true generalization items, which was not done in the previous studies (e.g. in Williams (2005) ‘ne cushions’ was used as a training item and ‘ro cushions’ was used for the generalization test). Other than this the procedure followed closely the procedure of Williams (2005).

They found that the experimental group performed at about 75% accuracy opposed to 49% accuracy in the trained control group. Analyzing the retrospective reports, their findings were that the 9 subjects that showed signs of awareness performed at 80% accuracy and the four unaware subjects at 58% accuracy. Thus their results are much like the results of Hama and Leow (2010) and Faretta-Stutenberg and Morgan-Short (2011) in that the unaware subjects performed either at chance or slightly above, yet not significantly so. The subjective measurements, on the other hand, clearly showed that low confidence ratings still correlated with above average accurate judgments and that even for the categories guess and intuition the subjects performed at about 70% accuracy, if at least somewhat confident in their choice. From this they concluded that the subjects developed at least some unconscious structural knowledge.

# 5. Methodological Changes to the Experimental Design

In light of those conflicting results this study had one objective. This objective was to confirm that at very low levels of awareness no learning can take place. In order to achieve this, a number of changes were made to the original design.

In the original study, all four artificial determiners were introduced in the description of the study. This might cause to the participants to think about the difference of the second artificial determiner, as they are told that it describes the same category and only a weak explanation for the difference is given, which is unlikely to prevent the participants from pondering on the nature of the difference between the determiners, especially as they know they are participating in a study. As this increases the chance for participants to consider some kind of form-meaning mapping, this is likely to result in more participants acquiring conscious knowledge of the form-meaning mapping. Even worse this might result in unaccounted low confidence level knowledge, which is hard to identify. To prevent this in this experiment the determiners were chosen in a way to make the difference between the animate and inanimate form less salient and to allow for the description to only include only two determiners, namely the inanimate forms. For the same reason in contrast to the original study, which employed 24 training items, shown six times each, the participants in this study were exposed only once to eight training items. Furthermore, those training items were embedded into a continuous natural language context, namely part of a short children story (see appendix), and their attention directed to the content by telling them they would be asked questions on the texts content.

In order to capture awareness of the form-meaning mapping as good as possible multiple measures of awareness were employed in this study. I used retrospective verbal reports, subjective measures alike to the ones used in Rebuschat et al. (2013) and an indirect production task. The indirect production task was a cloze asking the participants to “fill in the correct forms of the artificial determiner”, without explicitly mentioning the animate forms. If a participant employed an animate form at any point during the cloze, they were excluded from the unaware group. This was done, as any participant that explicitly noticed the new form and employed it in the cloze has a high chance of having thought about a form-meaning mapping related to the employed animate form. Furthermore, any participants mentioning any kind of rule concerning the different forms in the retrospective verbal reports were excluded. The subjective measures served as a control factor, to check for the zero correlation criterion. The only reason for not using concurrent verbal reports as well, were the limitations of the platform I employed, which made capturing think-aloud protocols unfeasible.

Finally I chose a different platform for this experiment. In order to get a larger number of participants I decided to develop this experiment using the crowdsourcing platform Crowdflower. Even though this has a number of disadvantages, some of them actually help in this study and it comes with advantages as well. While the immersion into the study can be considered lower as participants mostly complete the study to earn money and try to complete it as fast as possible, which also lead to a number of participants not engaging with the task and willingly giving wrong answers, at the same time this situation is much more natural and the low immersion also creates a situation better suited to implicit learning instead of explicit learning. Furthermore, measures were built into the study to filter those participants that willingly gave wrong answers (see procedure for examples).Using Crowdflower also has the advantage that the participants in this study have a much more diverse background than the participants in the original study and in its extensions, which were mostly students, often with linguistic backgrounds.

# 6. Method

## 6.1. Participants

The experiment included a total of 201 participants, 112 women and 89 men with a mean age of 39.1 years. 182 were native speaker of English and 41 spoke a second language. 32% of the participants had graduated college, 25% had an associate degree, 40% had a high school diploma and 3% had neither (Figure 1). The participants come from Australia (5%), Great Britain (28%) and from the USA (67%).

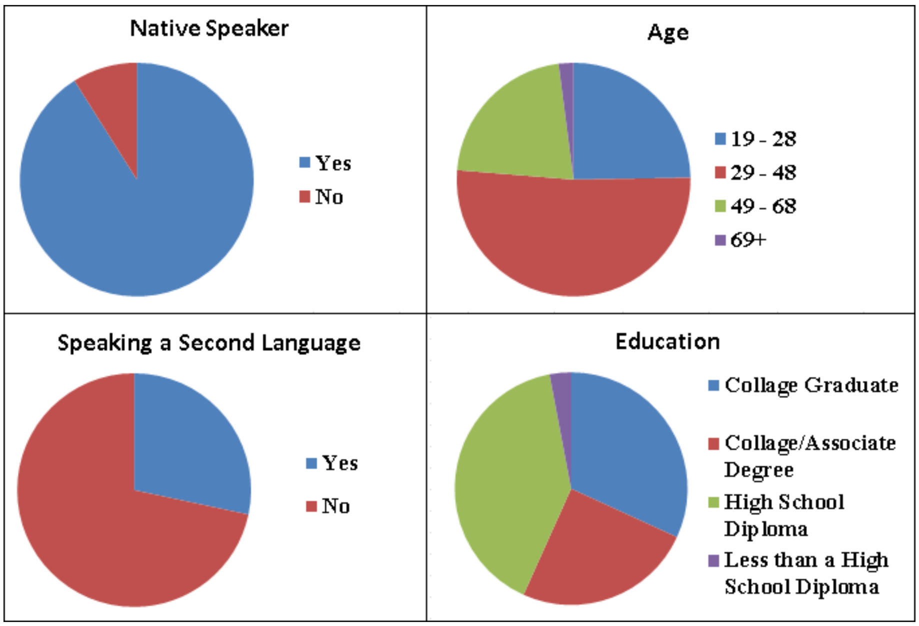



**Figure 1**: Metadata on Participants

## 6.2. Grouping of Participants:

For ease of reference the participants were each assigned to one of three groups. The most relevant group consists of all participants who showed no sign of awareness of any form-meaning connection on the different measures. This group was labeled as "unaware". The second group consisted of those participants who clearly showed signs of awareness and were able to verbalize the animacy rule to some extent. They were labeled as "aware". The final group consists of all participants that expressed some knowledge concerning a form-meaning alignment, but mentioned a non-animacy based strategy (among those were number, ownership of the object, and tense of the predicate). This group was labeled as “misguided”.

## 6.3. Materials

The artificial determiner system used in this experiment is inspired by Williams (2005). The system consists of two artificial determiners *hul* and *rel* which encode distance and are used to describe inanimate objects (e.g. instead of “I point at the distant moon” one can use “I point at rel moon”). These items were modified by adding the morpheme 't' at the end of the word when the referent object was animate. *Hul* and *hult* are thus used to refer to nearby objects while *rel* and *relt* are used for nouns that refer to distant objects (see table 2). I decided to mark the animacy contrast by just one letter in word-final positions in order to minimize the perceptual salience the form signaling animacy. As in the previous studies the participants were trained explicitly on the near/far distinction. In contrast to the previous studies the participants were only exposed to the inanimate forms of the artificial determiners in the vocabulary pre-training.

| | Near | Far |
|---|---|---|
| Inanimate | hul | Rel |
| Animate | hult | Relt |

**Table 2**: Artificial Determiners Used in this Study

The noun phrases used in the experiment for the different phases can be found in table 3. The words used differ significantly from the ones used in Williams (2005) as I embedded them in a consistent natural language context, which follows some scenes in the life of Bruce the bear in a children-like story, which was written for this experiment (extract below, full story attached).

> As he walked through the valley he spotted a herd of rabbits on the other side of a meadow. One of them started to approach Bruce. Relt rabbit was Mr. Fluffle.
>
> “I greet you kindly dear Bruce," he said once he reached Bruce. "I expect you are walking to relt bee queen in the pine forest to ask for some honey?"

This was done both to stay within one language domain and to direct the participant's attention on the content, and not on the novel forms, especially during the training phase. In order to support this focus further, the participants were provided with a content-related task. For all tasks the same amount of items were used for each determiner, two per determiner for the training and for the production task (eight in total), and four items each for the 2AFC task (16 in total) (see table 3). All noun phrases within this task are unique, however, for the training and the production task within one task the same noun will once appear with another artificial determiner. While this might lead to form-form associations (e.g. any noun that takes hul [near], also takes rel [far]), the items for the 2AFC task were restricted to true generalization items in order to prevent this from influencing the learning effect.

| | | | | |
|---|---|---|---|---|
| Pre-Training Items | hul ball | ——— | rel moon | ——— |
| Training Items | hul honey pot | hult rabbit | rel pine forest | relt rabbit |
| | hul cave | hult hare | rel river | relt bee queen |
| Production Task Items | hul bramble | hult boar | rel sky | relt leader |
| | hul tree | hult leader | rel bee hive | relt deer |
| Judgment Task Items | hul honey cake dough | hult bunny | rel rock | relt salmon |
| | hul carrot | hult stag | rel warren | relt hornet queen |
| | hul pinewood chest | hult fox | rel flower field | relt falcon king |
| | hul hive | hult doe | rel mountain | relt hedgehog |

**Table 3:** Noun Phrases Used in this Study

The experiment was conducted using the *Crowdflower* crowdsourcing platform. It was constructed manually using the Crowdflower API and written in HTML, JQuery and the Crowdflower Markup. The experiment was presented to the participants as a study on implicit language learning. The subpages of the experiment were presented on white background with black text in Verdana 16 points. After each task was completed the previous step was hidden and the next step displayed instead. The participants were required to navigate through the steps using one button on the lower right corner. They were not allowed to navigate to a previous page.

# 7. Procedure

**Step 1: Vocabulary Pre-Training:**

As in the previous studies (Williams, 2005; Hama & Leow, 2010; Faretta-Stuttenberg & Morgan-Short, 2011; Rebuschat et al., 2013) the participants were introduced to the novel determiners and their English translations during a pre-training activity. However, in contrast to those studies they were only shown the inanimate variant of the determiners. First they were shown a short description of the two determiners and their function and translation. Then they were shown two explained and illustrated example sentences of the inanimate form of the determiners (Figure 2). The Participants were allowed to engage with those materials for as long as they liked.

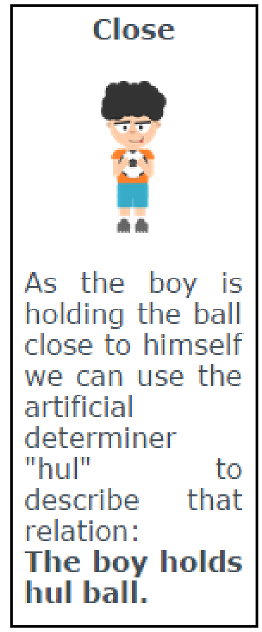



**Figure 2**: Illustrated Example

**Step 2: Training Task:**

In contrast to the previous studies the training was not done using isolated phrases. In this study the participants were exposed to the training items embedded in a natural language context which was presented as a single text on their screen. The Participants were asked to read the text for comprehension and were informed that they would be presented with content-related questions about the text.in the step to follow (see figure 3). Only in this phase the participants were exposed to the animate forms of the determiners. Those determiners were included in the text without being mentioned specifically (see figure 4).

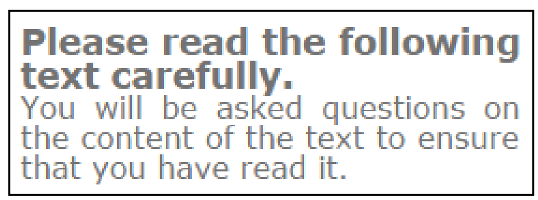

**Please read the following text carefully.**
You will be asked questions on the content of the text to ensure that you have read it.

**Figure 3:** Instructions for the Training Task

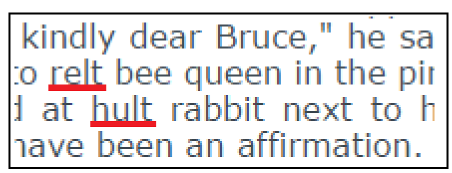

kindly dear Bruce," he sa
:o relt bee queen in the pi
l at hult rabbit next to h
have been an affirmation.

**Figure 4:** Animate Artificial Determiners

In order to assure engagement with the text the participant's comprehension was assessed on the basis of three multiple choice questions querying for fundamental information about interactions and situations in the story. Participants who did not correctly answer all three questions were sent back to Step 1 and asked to re-read the text. Answering the three questions correctly would lead to Step 3, i.e., the Cloze task.

**Step 3: Cloze Task:**

The Cloze task was presented as text containing eight small textboxes as gaps for the missing determiners. The instructions for the task were to "fill in the correct form of the artificial determiners" (see figure 5). The task description was kept vague in order to both avoid putting emphasis on the newly learned animate forms but at the same time ask for their usage, if they were noticed. This task was included as an additional filter for aware participants. The rationale behind this is that if a participant is aware of the animate forms of the artificial determiners and has any explicit suspicion of a form-meaning connection, (s)he the phrase "correct forms" in combination with the participant's metaknowledge of this test being part of a study will induce them to use the animate forms of the artificial determiners. This way participants could be tested for awareness without relying on their verbalization or subjective measures. Any participant using at least one animate form during this task would thus subsequently be tagged as aware. The participants could only continue the experiment once each text box was filled with one of the four determiners. If they tried to submit without having done so, the offending text boxes would be marked red and they would be prompted to review the marked text boxes (see figure 5).

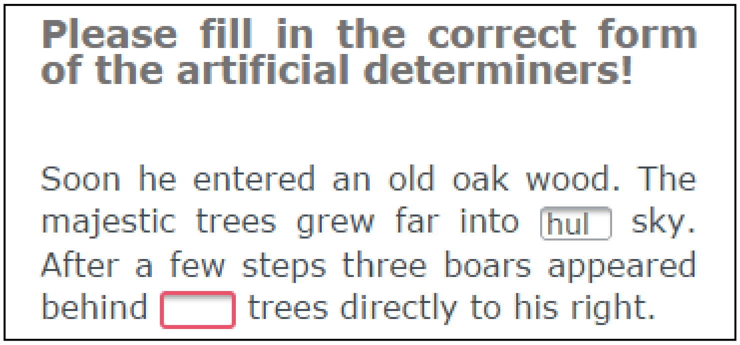



**Figure 5**: Description and Excerpt of the Cloze Task

Beyond this measurement of awareness this task also served as a filter to mark uncooperative participants. Since the distance dimension was explicitly taught, the participant's performance in this dimension could be used as a measure for their engagement with the task. Therefore, participants performing with 67.5% or less accuracy (5 out of 8) were tagged as uncooperative. The seemingly high level of accuracy was chosen, as this task only accepts the two determiners in their inanimate and animate form. Participants completing this task would thus perform at 50% accuracy on the distance dimension, even if using only one determiner during the whole task. At this point 44 participants had to be marked as uncooperative.

**Step 4: Two-Alternative Forced-Choice (2AFC) Task:**

After completion of the Cloze-task the participants were told about the additional determiners and that their usage is governed by a hidden rule. This was necessary, as during test-runs many participants were irritated by the sudden introduction of the novel animate forms of the determiners and many of them subsequently decided to be uncooperative. The participants were also told that they need not figure the rule out and that they can also decide intuitively.

The participants were then introduced to a two-alternative forced-choice (2AFC) task modeled on the one used in Williams (2005): Participants were presented a sentence with a gap which indicated the slot for the determiner. Alike to Rebuschat et al. (2013) the participants were asked to provide source attributions and indicate the level of certainty with which they made a given choice. Both quantities were assessed using a five point Likert scales (see figure 6).

Again, participants could only proceed to the next step when all required determiner choices had been made and the certainty level as well as the sources each choice had been specified. To avoid effect of order of presentation, both the sequence of items and the position of the determiner-buttons were randomly generated. Each participant saw four instances for each variant of the two determiners (hul, hult, rel, relt), for a total of sixteen items.

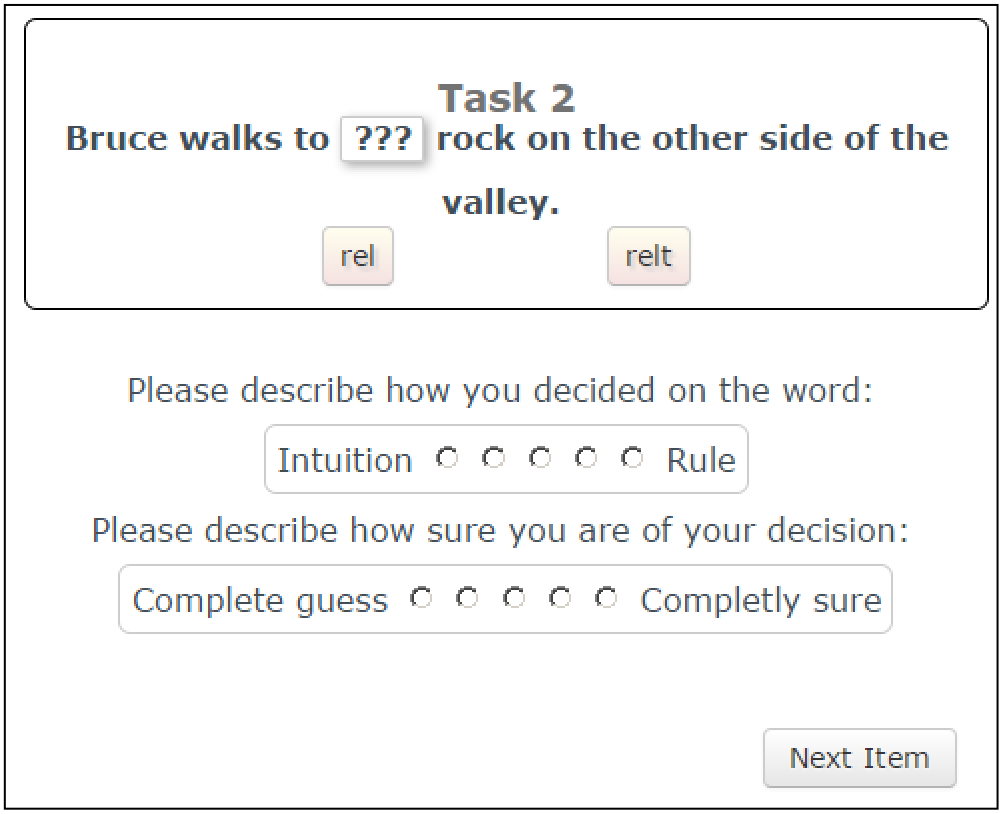



**Figure 6**: Screenshot of the 2AFC Task

As in the previous studies, performance on this task served as a measure for learning. But it also served as a measure for finding more uncooperative participants. For this I identified subjects who did either choose only the inanimate variants of the determiners (16 participants) or always chose to click the same button (13 participants).

**Step 5: Debriefing:**

During the debriefing the participants were asked to report whether they recognized the "hidden rule" governing usage of the four forms of the artificial determiner and were asked to describe the rule(s), if they found any. The data were collected and investigated for indicators of recognition of the correct rule or any other hypothesis about the regularity underlying the data. In order to prevent any form-meaning mapping from influencing the data all participants who mentioned any rule at all were removed from the participant pool considered unaware. The participants were also asked to provide some personal data which was used to check the distribution among different social groups. Finally they were offered a detail explanation of the experiment.

# 8. Results

## 8.1. Primary Results

Since the experiment was conceived in a way to prevent learning with awareness from taking place, 91 participants (73,4%) showed no signs of awareness of the form meaning alignment on any of the tests. However, 28 of them described non-animacy based strategies during the verbal reports and were subsequently removed from the unaware group as well. The remaining 63 unaware participants performed at 53.8% (SD=13,5%) accuracy slightly, but significantly ($p < .005$ in a two-sided binomial test) above chance. Furthermore, as can be seen in Figure 7 in contrast to the Aware group the Unaware group displayed no signs of learning during the task.

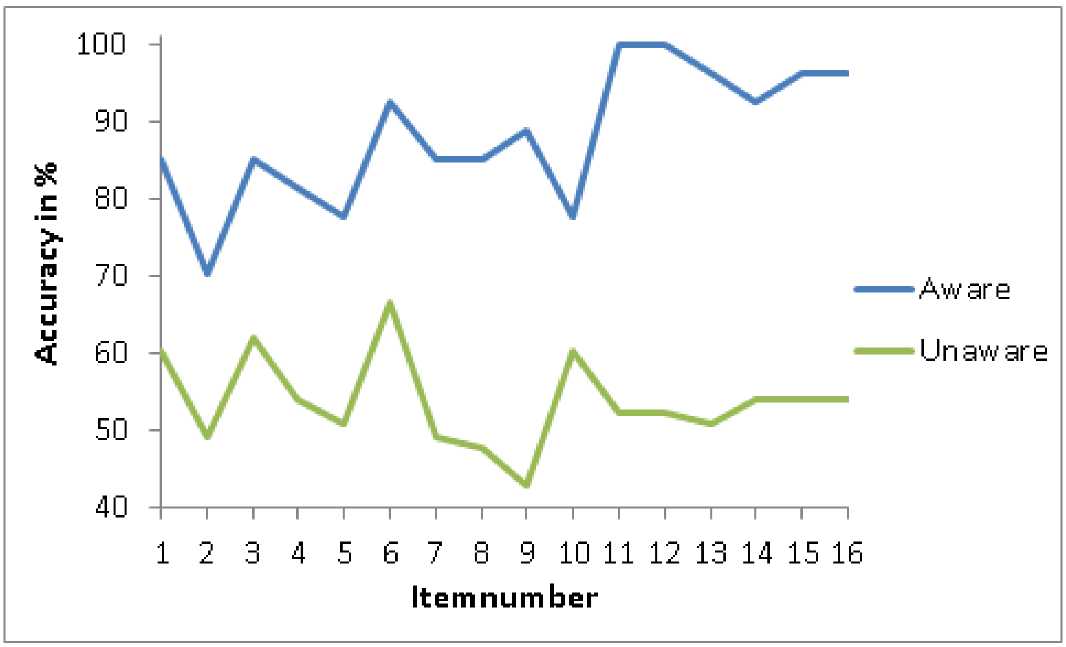



**Figure 7:** Performance during the 2AFC-Task

Analysis of the confidence ratings across the Unaware group yielded no significant results. The difference between high confidence judgments (55.7% [SD=14.3%]) and low confidence judgments (51.4% [SD=13.0%]) proved minimal and was not statistically significant in a multivariable ANOVA-test (Table 4). Similarly, no effects related to the subjective estimate of a participant as to whether their choice was based purely on intuition were found (also see Table 4). This serves as another piece of evidence for the participant's lack of awareness of the target form-meaning alignment, as the zero correlation criterion is fulfilled.

| | Df | Sum Sq | Mean Sq | F value | Pr(>F) | |
|---|---|---|---|---|---|---|
| item | 3.00 | 52.34 | 17.45 | 17.24 | 0.00 | *** |
| position | 1.00 | 0.15 | 0.15 | 0.15 | 0.70 | |
| s(rule.scale) | 1.00 | 0.49 | 0.49 | 0.48 | 0.49 | |
| s(certainty) | 1.00 | 2.94 | 2.94 | 2.91 | 0.09 | . |
| Residuals | 995.00 | 1006.86 | 1.01 | | | |

**Table 4**: Anova for Parametric Effects

Further analysis of the results has shown that the performance across the different items of the task was highly dependent on the determiner (see figure 8). These results indicate that the participants performed significantly better for the introduced determiners *hul* and *rel* (with the exception of item two, which is discussed below) and below chance level for the hidden modifications of the determiners *hult* and *relt*.

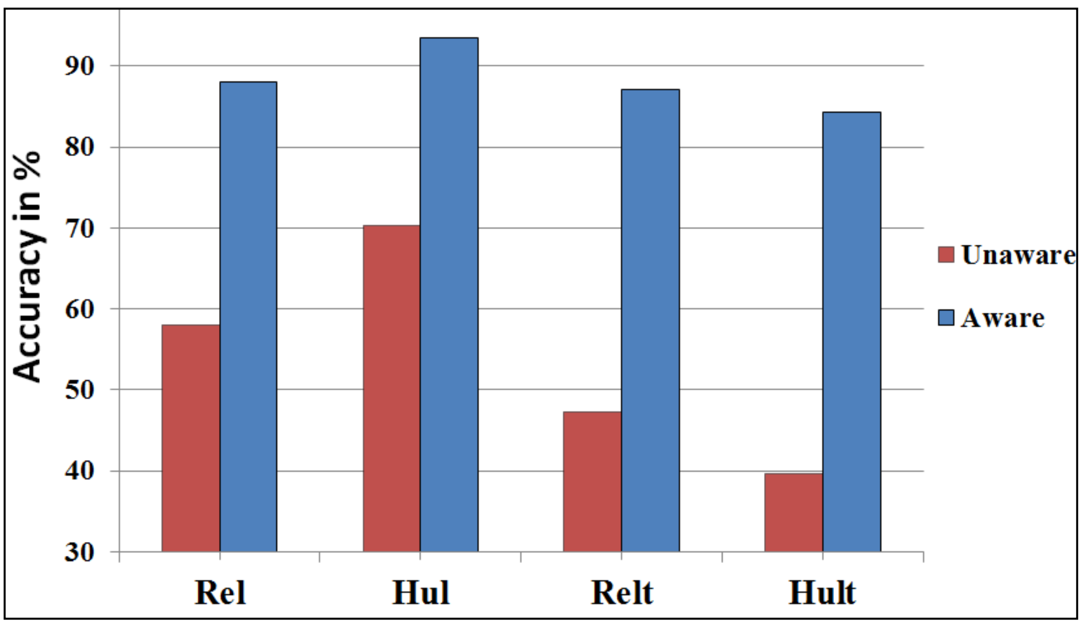



**Figure 8:** Performance across the Artificial Determiners in the 2AFC Task

While one might argue that this is further evidence against the existence of LwoA, as only for those items that were explicitly introduced an above average performance could be found, while the accuracy for the implicitly introduced forms is clearly below chance level, I could also find a significant overuse of the inanimate forms (table 5). As the inanimate forms had been 'officially' introduced and explained, they were much more salient than *hult* and *relt*. Especially the participants in the Unaware group, who did not notice those two of modifiers in the training phase were therefore very reluctant to use those new forms and preferred to use the more familiar forms (see chapter 9). For this reason they deviated from the ideal ratio in which they would have chosen each of the four determiner equally often.

| | Hul | Rel | Hult | Relt |
|---|---|---|---|---|
| Aware | 1% | 9% | -1% | -9% |
| Unaware | 11% | 31% | -11% | -31% |

**Table 5:** Deviation from expected usage

Therefore, I had to look at the data from another perspective in order to get relevant information and judge whether learning took place for the animate forms as well. For this it was necessary to check the accuracy from the determiner side (e.g. if a participant decides to use hult, is it in a question that requires him to use hult). As this variant of measuring the per-item accuracy is less susceptible to overuse of specific forms, it offers a totally different picture:

| | Unaware | | | | Aware | | | |
|---|---|---|---|---|---|---|---|---|
| | Accuracy | N | K | p | Accuracy | N | K | p |
| Hul | 53,8% | 329 | 177 | 0,093 | 85,6% | 118 | 101 | <0.001 |
| Hult | 57,1% | 175 | 100 | 0,035 | 92,9% | 98 | 91 | <0.001 |
| Rel | 52,3% | 279 | 146 | 0,236 | 87,2% | 109 | 95 | <0.001 |
| Relt | 52,9% | 225 | 119 | 0,212 | 87,9% | 107 | 94 | <0.001 |

**Table 6:** Accuracy for Employed Items

This shows that the learning effect is about the same for the inanimate and the animate forms of the determiner. Actually the only determiner that is statistically significant above average is hult, an animate form. Looking at the matter from this perspective, the overuse of inanimate forms is due to a separate effect and interferes with the learning effect in a negative way and therefore, if it is avoided the LwoA should show more clearly.

## 8.2. Secondary Results

The 24 participants that qualified for the Aware group performed both strongly and significantly above chance level with an average accuracy of 88.2% (SD=11.2%) and, as displayed in Figure 7, showed a strong learning effect. Interestingly this does not reflect in the confidence ratings at all. In most cases I found a linear development and in some cases confidence ran counter to accuracy.

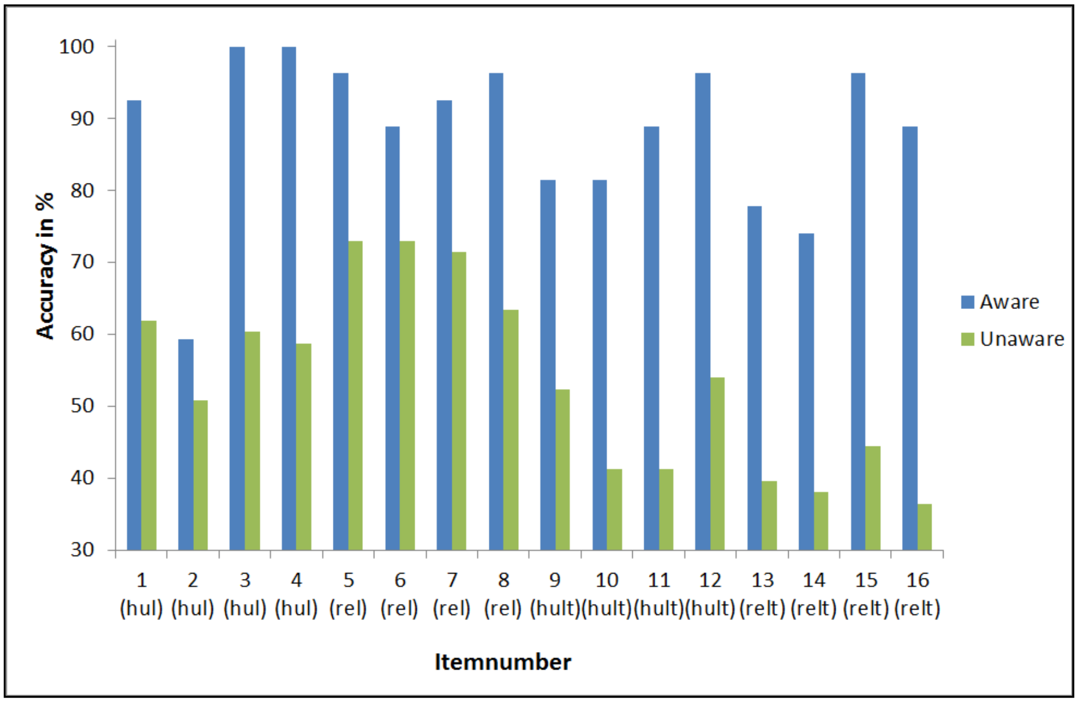
Non-native English speakers seemed to outperform native speakers within the same group, but only by a very small margin. However, across the groups there are more non-native English speakers in the Aware and Misguided groups than in the Unaware group (see table 7). This may be due to statistical irregularities as the data pool for this is rather small. On the other hand this seems to be in line with prior research which showed that participants with a more diverse linguistic background and native speakers of languages with a rich morphological inflection system are able to perform better on such AGL-tasks (also see chapter 9). The same is true for English speakers that are able to speak such a language as second language.

| | Aware | Misguided | Unaware |
|---|---|---|---|
| Non-Native English Speaker | 18% | 18% | 3% |
| Able to Speak Second Language | 55% | 50% | 22% |

**Table 7:** Language Backgrounds across Groups

An item-specific accuracy analysis (figure 9) also allowed some conclusions concerning which items are considered difficult to learn. Two items are of special significance: item 2 and item 9. Item 2 is "warren" and the most uncommon word in the experiment (freq. of 1.8 per million in COCA compared to 3.8 for doe which is the second rarest word used). This seems to confuse the participants as the error rate is significantly higher compared to the other items associated with rel. This implies that uncommon words are easier associated with new or uncomfortable forms. This is only a single occurrence, but this might justify further analysis.

The second item to cause unusual effect, item 9 is "salmon", which can be interpreted as plural, as the natural language context provides no clear specification of the plurality and as such is consistent with some incorrect hypotheses about the form-meaning alignment concerning number, which was reported by some participants. A number of comments mention number as rule even though the study only uses nouns in singular but the one in item 9. This explains why there is an above average accuracy for item 9 by the Unaware-group.




This is likely due to the highly salient nature of the number attribute and due to the fact that English speakers are used to synthetic modification of words in plural.

**Figure 9:** Performance across 2AFC-Task Items

# 9. Discussion

This experiment sought to contribute to the ongoing debate on implicit statistical language learning without awareness. Specifically, I set out to examine if evidence for learning without awareness could still be found in a design that is strongly biased against the possibility of wrongly including episodes of learning with awareness. I achieved this by hiding the contrastive animate form. As without the modified form it is impossible to learning the form-meaning alignment, lack of conscious knowledge of the relevant form prevents the formation of conscious knowledge of a form-meaning. Additionally, in contrast to previous research (Williams, 2005; Hama and Leow, 2010; Faretta-Stutenberg and Morgan-Short, 2011; Rebuschat, 2013; Rebuschat, 2015), this experiment included a new gating mechanism in order to test for aware participants before subjected them to the 2AFC-Task and employed three independent measures of awareness (indirect production test, subjective measures of awareness and retrospective reports). Other problems identified in earlier studies, as for example an above average amount of participants with a linguistic background, could be avoided by the large amount of participants and the good distribution across different levels of education, gender and age.

Despite all these measures to identify participants that have developed some degree of awareness and remove them from the target group and to exclude group specific effects, I was still able to find a weak but significant effect of LwoA. At a first glance this seems out of line with the recent results of the previous replications, however, if looking at their results closely, one can find in nearly all other replications that the accuracy of the unaware participants is above chance level, however not significantly so (see table 7). This regularity across different studies despite different authors and variations in methodology reinforce this study's finding that learning at very low levels of awareness is possible. This is further reinforced by Rebuschat et al.'s (2013) findings, from which they concluded that even if some parts of the knowledge are conscious, this does not imply that all of the knowledge is conscious and that there are no unconscious aspects of knowledge at all. This makes the findings of this study all the more important, as I was able to show a weak effect of LwoA, and this proves that there is an unconscious aspect to the learning of form meaning alignments.

| | **Accuracy of Unaware Participants in the Experimental Task** | | |
|---|---|---|---|
| **Williams (2005)** | **Generalization 1** | **Generalization 2** | **Generalization 3** |
| | 56,8% | 60,2%* | 59,2%* |
| **Hama and Leow (2010)** | **Judgment Task** | **Production Task** | |
| | 48,4% | 50,4% | |
| **Faretta-Stutenberg and Morgan-Short (2011)** | | **Generalization 1** | **Generalization 2** |
| | **Unaware** (noticing + no noticing) | 53,0% | 54,8% |
| | **No noticing** | 48,1% | 52,9% |
| **Rebuschat (2013)** | **New Items** | **Mean Performance** | |
| | 56.3% | 58.4% | |

**Table 7:** Accuracy of Unaware Participants in Different Studies

Also the fact that participants had problems learning the less salient animate forms is in line with previous research. Ellis (2005) pointed out the importance of salience for the acquisition of forms. Animacy is a meaning component that is already included in the noun and while focused on the distance component of the new artificial determiners these new forms might easily be shaded by the more salient form-distance mapping. Secondary cues will only be added to the mix if participants have a firm grasp of the primary cue. It is likely that this cue was only learned due to the special experimental situation and the additional focus it thus received, as the primary cue works well enough to allow everyday communication (after all animacy is not marked in English) (see also Terrell, 1991; Matessa & Anderson, 2000; Cheng & Holyoak, 1995; Kruschke & Blair, 2000; Shanks, 1995, chapter 2).

This also helps to explain, why participants with a L1 other than English achieved higher levels of awareness. If they have a L1 that has a more complex morphological system than English they might be used to look for different cues than English native speakers (James, 1980; Odlin, 1989). This kind of cue strength hierarchy only resets after considerable L2-Experience (MacWhinney, 1987), if at all (MacWhinney, 2001a).

Due to my modifications to the determiner and the much shorter training phase I was also able to gain some insights into the amount of exposure that is necessary to learn and generalize form-meaning alignments. In this study the exposure was strongly reduced compared to the previous studies (Williams, 2005; Hama and Leow, 2010; Faretta-Stutenberg and Morgan-Short, 2011; Rebuschat, 2013; Rebuschat, 2015), yet performance of the participants remains comparable to the previous studies. This implies that, at least within a natural language context, minimal exposure remains sufficient for the brain to process the regularities. However, due to technical limitations I was unable to assess the exact amount of exposure the participants received. A post-experimental test with only few participants showed an average exposure of about 90 to 120 seconds per participant. During this time the participants had to read a text containing 280 words, which comes down to about 0,3-0,5 seconds per word. Beyond the implicitly acquired knowledge, a relatively large group was able to acquire the form-meaning alignment explicitly. While this shows that relatively little exposure is necessary to learn form-meaning alignments in a natural language context, the question how much exposure exactly is necessary for learning to emerge. These findings are in line with recent research from Bisson et al. (2013). They tested for both implicit and explicit learning of new words in a foreign language and found that their participants showed rapid learning of the foreign language words in the incidental learning phase. Carey and Bartlett (1978) described this process as *fast mapping,* a process in which bare-bones representations are formed and placed in lexical-semantic memory. This kind of learning comes with severe limitations and allows participants to perform well on comprehension tasks, but not on production tasks (Carey and Bartlett 1978; Dollaghan 1985, 1987).

The findings of this thesis also shed some new light on the findings of Hoffmann and Sebald (2005), who found that their participants were unable to learn a co-variation between the position of the task relevant items (certain card types, either a specific number or a specific suit) and the clearly visible backside of playing cards placed directly next to the task-relevant items. In light of the results of this study the generalizability of this finding is questionable. It seems likely that the brain needs to be trained to look implicitly for specific co-variations. While this is not true for a number-picture mapping, it is very much the case for form-meaning mappings in language. This point remains for another study to analyze.

# 10. Conclusion

This thesis sought to contribute to the discussion on whether learning of form-meaning alignments is possible by focusing on participants whose unawareness had been ensured by combining four independent measures of awareness and by designing the experiment to be biased against learning with awareness. This allowed conclusions to be drawn about unconscious learning processes at very low levels of awareness, as despite all these measures to ensure unawareness a weak learning effect was found.

These findings were able shed new light on the findings of the preceding extensions unifying their results that were previously conflicting, by isolating this very weak implicit learning effect, which other studies were unable to find due to smaller sample sizes.

Furthermore, evidence was found that minimal exposure might suffice for this kind of learning to take place. In contrast to previous studies this thesis employed no extensive learning phase. This implies that on a very basic level the brain is able to rapidly compute statistical regularities and abstract rules from them. As the exact amount of exposure was not explored in this thesis, this might remain a fruitful area for further inquiry.

## References


Allen, R. & Reber, A. S. (1980). Very long term memory for tacit knowledge. *Cognition,* 8, 175-185.

Andringa, S. & Rebuschat, P. (Eds.). (2015). New directions in the study of implicit and explicit learning. *Thematic issue of Studies in Second Language Acquisition*, 37(2).

Balota, D. A. (1983). Automatic semantic activation and episodic memory encoding. *Journal of Verbal Learning and Verbal Behavior*, 22, 88-104

Berry, D. C. & Dienes, Z. (1993). Implicit learning: Theoretical and empirical issues. *Hove*: 227

Bisson, M. J., van Heuven, W. J. B., Conklin, K. & Tunney, R. J. (2013) Incidental Acquisition of Foreign Language Vocabulary through Brief Multi-Modal Exposure. *PLoS ONE* 8(4).

Bowles, M. (2003). The effects of textual input enhancement on language learning: An online offline study of fourth-semester Spanish students. In: P. Kempchinsky & C. E. Piñeros (Eds.), *Theory, practice & acquisition: Papers from the 6th Hispanic Linguistics Symposium and the 5th Conference on the Acquisition of Spanish and Portuguese.* pp. 395–411. Somerville, MA: Cascadilla Press.

Bowles, M. (2004). L2 glossing: To CALL or not to CALL. *Hispania*, 87, 543–555.

Braine, M. D. S. (1963).. On learning the grammatical order of words. *Psychological Review*, 70(4), 323-348.

Braine, M. D. S. (1966).. Learning the positions of words relative to a marker element. *Journal of Experimental Psychology*, 72, 532-540.

Buchner, A. et al. (1998). On the role of fragmentary knowledge in a sequence learning task. *Q. J. Exp. Psychol.* 51A, 251–281

Chan, C. (1992). Implicit cognitive processes: Theoretical issues and applications in computer systems design. *Unpublished DPhil thesis*, University of Oxford.

Channon S., Shanks D., Johnstone T., Vakili K., Chin J. & Sinclair E. (2002). Is implicit learning spared in amnesia? Rule abstraction and item familiarity in artificial grammar learning. *Neuropsychologia* 40.

Carey, S., & Bartlett, E. (1978). Acquiring a single new word. *Proceedings of the Stanford Child Language Conference*, 15, 17–29.

Cheesman, J. & Merikle, P. M. (1984). Priming with and without awareness. *Perception & Psychophysics, 36*(4), 387-395.

Cheesman, J. & Merikle, P. M. (1996). Distinguishing conscious from unconscious perceptual processes. Can. J. Psychol., 40: 343-367 *Handbook of second language acquisition* (pp. 313-348). Oxford: Blackwell.

Cheng, P. W., & Holyoak, K. J. (1995). Adaptive systems as intuitive statisticians: Causality, contingency, and prediction. In J.-A. Meyer & H. Roitblat (Eds.), *Comparative approaches to cognition* (pp. 271–302). Cambridge, MA: MIT Press.

Cleeremans, A. & McClelland, J. L. (1991). Learning the structure of event sequences. *Journal of Experimental Psychology*: General, 120, 235-253.

Cleeremans, A., Destrebecqz, & Boyer, M. (1998). Implicit learning: news from the front. *Trends in Cognitive Sciences, 2,* 406-417.

Cohen, A., Ivry, R. I. & Keele, S. W. (1990). Attention and structure in sequence learning. *Journal of Experimental Psychology*: Learning, Memory & Cognition, 16, 17–30.

Conway, C. M. & Christiansen, M. H. (2006). Statistical learning within and between modalities: Pitting abstract against stimulus-specific representations. *Psychological Science*, 17, 905-912.

Curran, T. & Keele, S. W. (1993). Attentional and nonattentional forms of sequence learning. *Journal of Experimental Psychology*: Learning, Memory & Cognition, 19, 189–202.

DeKeyser, R. (2003). Implicit and explicit learning. In: C. Doughty & M. H. Long (Eds.), *Handbook of second language acquisition* (pp. 313-348). Oxford: Blackwell.

DeKeyser, R. M. (1995). Learning second language grammar rules: an experiment with a miniature linguistic system. *Studies in Second Language Acquisition, 17,* 379-410.

Dell, G. S., Reed, K. D., Adams, D. R. & Meyer, A. S. (2000). Speech errors, phonotactic constraints & implicit learning: A study of the role of experience in language production. *Journal of Experimental Psychology*: *Learning, Memory & Cognition*, 26, 1355–1367.

Dienes, Z. & Berry, D. C. (1997). Implicit learning: Below the subjective threshold. *Psychonomic Bulletin and Review*, 4, 3-23.

Dienes, Z. & Fahey, R. (1995). The role of specific instances in controlling a dynamic system. *Journal of Experimental Psychology*: Learning, Memory, & Cognition, 21, 848-862.

Dienes, Z. & Longuet Higgins, H. C. (2004). Can musical transformation be implicitly learned? *Cogn Sci.*, 28: 531-558.

Dienes, Z., & Perner, J. (1999). A theory of implicit and explicit knowledge. *Behavioural and Brain Sciences*, 22, 735-755.

Dienes, Z. & Scott, R. (2005). Measuring unconscious knowledge: distinguishing structural knowledge and judgment knowledge. *Psychological Research*, 69(5-6), 338-351.

Dienes, Z. (2012). Conscious versus unconscious learning of structure (pp. 337 – 364). In: P. Rebuschat & J. N. Williams (Eds.) *Statistical learning and language acquisition*. Berlin: Mouton de Gruyter.

Dienes, Z., Altmann, G., Kwan, L. & Goode, A. (1995). Unconscious knowledge of artificial grammars is applied strategically. *Journal of Experimental Psychology*: Learning, Memory & Cognition, 21(5), 1322-1338.

Dienes, Z., Broadbent, D. E. & Berry, D. C. (1991). Implicit and explicit knowledge bases in artificial grammar learning. *Journal of Experimental Psychology: Learning, Memory, & Cognition, 17,* 875-882.

Diessel, H. (2011). Grammaticalization and language acquisition. In: B. Heine & H. Narrog (eds), *Handbook of Grammaticalization* (pp. 130–141). Oxford: Oxford University Press.

Dollaghan, C. (1985). Child meets word: “Fast mapping” in preschool children. *Journal of Speech & Hearing Research*, 28, 449–454.

Dollaghan, C. (1987). Fast mapping in normal and language-impaired children. *Journal of Speech & Hearing Disorders*, 52, 218–222.

Dulany, D. E., Carlson, R. & Dewey, G. (1984). A case of syntactical learning and judgement: How concrete and how abstract? *Journal of Experimental Psychology*: Learning, Memory & Cognition, 113, 541-555

Ellis, N. (2011). Implicit and explicit SLA and their interface. In: C. Sanz & R. P. Leow (Eds.), *Implicit and explicit language learning: conditions, processes & knowledge in SLA and bilingualism* (pp. 35-49). Georgetown: Georgetown University Press.

Ellis, N. (Ed.) (1994). *Implicit and explicit learning of languages*. London: Academic Press.

Ellis, R., Loewen, S., Elder, C., Erlam, R., Philp, J., & Reinders, H. (2009). *Implicit and explicit knowledge in second language learning, testing and teaching*. Bristol, UK: Multilingual Matters.

Ellis, R. (2005). Measuring implicit and explicit knowledge of a second language: A psychometric study. *Studies in Second Language Acquisition*, 27, 141-172.

Ellis, R. (2015). Form-focused instruction and the measurement of implicit and explicit L2 knowledge. In: Rebuschat, Patrick (ed.), *Implicit and Explicit Learning of Languages*. 2015. xxii, 482 pp.

Ericsson, K. A. & Simon, H. A. (1980). Verbal reports as data. *Psychological Review*, 87(3), 215-251.

Faretta-Stutenberg, M. & Morgan-Short, K. (2011). Learning without awareness reconsidered: A replication of Williams (2005). In: G. Granena, J. Koeth, S. Lee-Ellis, A. Lukyanchenko, G. Prieto Botana, & E. Rhoades (Eds.), *Selected proceedings of the 2010 Second Language Research Forum*

Fowler, C. A., Wolford, G., Slade, R. & Tassinary, L. (1981). Lexical access with and without awareness. *Journal of Experimental Psychology*: General, 110, 341-362.

Frensch, P. A., Buchner, A. & Lin, J. (1994). Implicit learning of unique and ambiguous serial transitions in the presence and absence of a distractor task. *Journal of Experimental Psychology*: Learning, Memory & Cognition, 20, 567–584.

Gass & Selinker, (2001). *Second Language Acquisition: An Introductory Course*. (2nd edition). London: Publishers Mahwah.

Gerken, L. A. (2006). Decisions, decisions: Infant language learning when multiple generalizations are possible. *Cognition*. 98.

Godfroid, A. & Schmidtke, J. (2013). What do eye movements tell us about awareness? A triangulation of eye-movement data, verbal reports and vocabulary learning scores. In: J. M. Bergsleithner, S. N. Frota & J. K. Yoshioka (Eds.), *Noticing and second language*

Godfroid, A., & Winke, P. M. (2015). Investigating implicit and explicit processing using L2 learners' eye-movement data. In P. Rebuschat (Ed.), *Implicit and explicit learning of languages*. John Benjamins.

Gomez, R. L. (2002). Variability and detection of invariant structure. *Psychol Sci*, 13:431–436.

Gomez, R. L. & Maye J. (2005). The developmental trajectory of nonadjacent dependency learning. *Infancy,* 7: 183–206.

Gómez, R. L. (2007). Statistical learning in infant language development. In: M. G. Gaskell (Ed.), *The Oxford Handbook of Psycholinguistics.* Oxford: Oxford University Press.

Gómez, R. L., & Gerken, L. A. (1999). Artificial grammar learning by 1-year-olds leads to specific abstract knowledge. *Cognition*, 70, 109-135.

Green, D. M. & Swets, J. A. (1966). *Signal detection theory and psychophysics*. New York: Wiley.

Green, P. & Hecht, K. (1992). Implicit and explicit grammar: An empirical study. *Applied Linguistics*, 13, 168-184.

Gregg, K. R. (1984). 'Krashen's Monitor and Occam's Razor.' *Applied Linguistics* 5(2): 79-100.

Grey, S. E., Williams, J. N. & Rebuschat, P. (2014). Incidental exposure and L3 learning of morphosyntax. *Studies in Second Language Acquisition*, 36, 1-34.

Hama, M. & Leow, R. P. (2010). Learning without awareness revisited: Extending Williams (2005). *Studies in Second Language Acquisition*, 32(3), 465-491.

Hamrick, P. & Rebuschat, P. (2012). How implicit is statistical learning? . In: P. Rebuschat & J. N. Williams (Eds.) *Statistical learning and language acquisition* (pp. 365-382). Berlin: Mouton de Gruyter.

Hayes, N. A. & Broadbent, D. E. (1988). Two modes of learning for interactive tasks. *Cognition, 28,* 249-276.

Heuer, H. & Schmidtke, V. (1996). Secondary-task effects on sequence learning. *Psychological Research*, 59, 119-133.

Hoffmann, J. & Sebald, A. (2005). When obvious covariations are not even learned implicitly. *European Journal of Cognitive Psychology*, 17, 449-480

Hsiao, A. T. & Reber, A. S. (2001). The dual-task SRT procedure: Fine-tuning the timing. Psychonomic Bulletin & Review, 8, 336–342. Schvaneveldt, R. W. & Gomez, R. L. (1998). Attention and probabilistic sequence learning. *Psychological Research*, 61, 175–190.

Hulstijn, J. H. (2003). Incidental and intentional learning. In: C. Doughty & M. Long (Eds.), *Handbook of second language acquisition* (pp. 349–81). Oxford, England: Blackwell.

Hulstijn, J. H. & Ellis, R. (Eds.). (2005). Implicit and explicit second-language learning. *Thematic issue of Studies in Second Language Acquisition,* 27(2).

Hunt, R. H. & Aslin, R. N. (2001). Statistical learning in a serial reaction time task: Access to separable statistical cues by individual learners. J. Exp. Psychol. Gen. 130, 658–680

James, C. (1980). *Contrastive analysis*. London: Longman.

Jiménez, L., Méndez, C. & Cleeremans, A. (1996). Comparing direct and indirect measures of sequence learning. *Journal of Experimental Psychology*: Learning, Memory & Cognition 22 (4), 948

Kihlstrom, J. F. (2004). Availability, accessibility & subliminal perception. *Consciousness and Cognition*, 13, 92–100.

Knowlton, B., Ramus, S. & Squire, L. (1992). Intact artificial grammar learning in amnesia: Dissociations of classification learning and explicit memory for specific instances. *Psychological Science*, 3, 172-179.

Krashen, S. D. (1977). The Monitor Model for adult second language performance. In: M. Burt, H. Dulay & M. Finocchiaro (Eds.), *Viewpoints on English as a Second Language: In honor of James E. Alatis* (pp. 152-161). New York: Regents Publishing.

Krashen, S. D. (1979). The Monitor Model for second language acquisition. In: R. Gingras (Ed.), *Second language acquisition and foreign language teaching* (pp. 1-26). Arlington, VA: Center for Applied Linguistics.

Krashen, S. D. (1981). *Second language acquisition and second language learning*. Oxford: Pergamon.

Krashen, S. D. (1985). *The input hypothesis.* London: Longman.

Krashen, S. D. (1994). The Input Hypothesis and its rivals. In: N. C. Ellis (Ed.), *Implicit and explicit learning of languages* (pp. 45-77). London: Academic Press.

Krosnick, J. A., Betz, A. L., Jussim, L. J., Lynn, A. R., 1992. Subliminal conditioning of attitudes. *Pers. Soc. Psychol. Bull*. 18, 152–162.

Kruschke, J. K., & Blair, N. J. (2000). Blocking and backward blocking involve learned inattention. *Psychonomic Bulletin and Review*, 7, 636–645.

Kuhl, P. K. (2004). Early language acquisition: cracking the speech code. *Nature Reviews Neuroscienc*e, 5(11):831-843.

Laufer, B. (1997). *'What's in a word that makes it hard or easy: Some intralexical factors'*. Cambridge: Cambridge University Press. Lawrence Erlbaum.

Leow, R. P. & Bowles, M. (2005). Attention and awareness in SLA. In: C. Sanz (Ed.), *Mind and context in adult second language acquisition* (pp. 179-203). Washington, DC: Georgetown University Press.

Leow, R. P. & Hama, M. (2013). Implicit learning in SLA and the issue of internal validity: A response to Leung and Williams (2011). *Studies in Second Language Acquisition*, 35(3), 545-557.

Leow, R. P. & Morgan-Short, K. (2004). To think aloud or not to think aloud: The issue of reactivity in SLA research methodology. *Studies in Second Language Acquisition*, 26(1), 35-57.

Leow, R. P. (1997). Attention, awareness & foreign language behavior. *Language Learning*, 47(3), 467-505.

Leow, R. P. (1998). Toward operationalizing the process of attention in SLA: Evidence for Tomlin and Villa's (1994). fine-grained analysis of attention. *Applied Psycholinguistics*, 19(1), 133-159.

Leow, R. P. (2000). A study of the role of awareness in foreign language behavior: Aware versus unaware learners. *Studies in Second Language Acquisition*, 22(4), 557-584.

Leow, R. P., Grey, S., Marijuan, S. & Moorman, C. (2014). Concurrent data elicitation procedures, processes & the early stages of L2 learning: A critical overview. *Second Language Research,* 30 (2), 111-127.

Leung, J. H. C. & Williams, J. N. (2011). The implicit learning of mappings between forms and contextually-derived meanings. *Studies in Second Language Acquisition*, 33(1), 33- 55.

Lewicki, P., Hill, T. & Bizot, E. (1988). Acquisition of procedural knowledge about a pattern of stimuli that cannot be articulated. *Cognitive Psychology,* 20, 24-37.

Marcel, A. (1980). Conscious and preconscious recognition of polysemous words: Locating the selective effects of prior verbal context. In: Nickerson (Ed.), *Attention and performance (Vol. VIII)*. Hillsdale, NJ: Erlbaum.

Marcel, A. J. (1983). Conscious and unconscious perception: An approach to the relations between phenomenal experience and perceptual processes. *Cognitive Psychology,* 15, 238-300.

MacWhinney, B. (1987). Applying the competition model to bilingualism. *Applied Psycholinguistics*, 8, 315–327.

MacWhinney, B. (2001). The competition model: The input, the context, and the brain. In P. Robinson (Ed.), *Cognition and second language instruction* (pp. 69–90). New York: Cambridge University Press.

Matessa, M., & Anderson, J. R. (2000). Modeling focused learning in role assignment. *Language & Cognitive Processes*, 15, 263–292.

McGeorge, P. & Burton, M. (1989). The effects of concurrent verbalization on performance in a dynamic system. *British Journal of Psychology*, 80, 455-465.

McLaughlin, B. (1978). The monitor model: Some methodological considerations. *Language Learning*, 28, 309 – 332.

McLaughlin, B. (1987). *Theories of Second Language Learning*. London: Arnold.

Merikle, P. M. & Daneman, M. (1998). Psychological investigations of unconscious perception. *Journal of Consciousness Studies*, 5, 5–18.

Merikle, P. M., Smilek, D. & Eastwood, J. D. (2001). Perception without awareness: Perspectives from cognitive psychology. *Cognition*, 79, 115–134.

Merikle, P. M. (1992)., Perception without awareness: Critical issues, *American Psychologist*, 47, pp. 7925.

Miller, G. A. (1958). Free recall of redundant strings of letters. *Journal of Experimental Psychology*.

Misyak, J. B., Goldstein, M. H. & Christiansen, M. H. (2012). Statistical-sequential learning in development. In: P. Rebuschat & J. N. Williams (Eds.). *Statistical learning and language acquisition* (pp. 13-54). Berlin: Mouton de Gruyter.

Moeser, S. D. & Bregman, A. S. (1972). The role of references in the acquisition of a miniature artificial language. *Journal of Verbal Learning and Verbal Behavior*, 11, 759-769.

Newport, E. L. & Aslin, R. N.(2004). Learning at a distance I. Statistical learning of non-adjacent dependencies. *Cognit Psychol*, 48:127–162.

Nisbett, R. E. & Wilson, T. D. (1977). Telling more than we can know: Verbal reports on mental processes. *Psychological Review*, 84(3), 231-259.

Norris, J. & Ortega, L. (2001). Does type of instruction make a difference? Substantive findings from a meta-analytic review. *Language Learning 51,* 157–213

Odlin, T. (1986). On the nature and use of explicit knowledge. *IRAL*, 24, 123-144.

Odlin, T. (1989). *Language transfer*. New York: Cambridge University Press.

Onnis L., Destrebecqz, A., Christiansen, M. H., Chater, N. and Cleeremans, A. (in press). Implicit learning of non-adjacent dependencies: A graded, associative account. In: Rebuschat, Patrick (ed.), *Implicit and Explicit Learning of Languages*. 2015.

Orrell, A., Eves, F., Masters, R. & Macmahon, K. (2007). Implicit sequence learning processes after unilateral stroke. *Neuropsychological Rehabilitation* 17: pp. 335-354.

Paciorek, A., & Williams, J. N. (2015). Semantic Generalization in Implicit Language Learning. *Journal of Experimental Psychology: Learning, Memory, and Cognition.*

Payne, J. W. (1994). Thinking aloud: Insights into information processing. *Psychological Science, 5*, 241- 248.

Pena, M., Bonatti, L., Nespor, M. & Mehler, J. (2002). Signal-driven computations in speech processing. *Science*, 298:604.

Perruchet, P. & Amorim, P. A. (1992). Conscious knowledge and changes in performance in sequence learning: evidence against dissociation. *Journal of Experimental Psychology*: Learning, Memory and Cognition, 18, 785-800.

Perruchet, P. & Pacteau, C. (1990). Synthetic Grammar Learning - Implicit Rule Abstraction or Explicit Fragmentary Knowledge. *Journal of Experimental Psychology-General*, 119(3), 264-275.

Perruchet, P. & Pacton, S. (2006). Implicit learning and statistical learning: One phenomenon, two approaches. *Trends in Cognitive Science, 10(5)*, 233-238.

Perruchet, P. & Poulin-Charronat, B., (in press). The learnability of language: Insights from the implicit learning literature. In: Rebuschat, Patrick (ed.), *Implicit and Explicit Learning of Languages*. 2015.

Perruchet, P., Tyler, M. D., Galland, N. & Peereman, R. (2004). Learning nonadjacent dependencies: no need for algebraic-like computations. *J Exp Psychol Gen*, 133:573–583.

Perruchet, P. (2008). Implicit learning. In: H. Roediger (Ed.), *Cognitive psychology of memory. Vol. 2 of learning and memory: A comprehensive reference* (pp. 597-621). Oxford: Elsevier.

Reber, A. S. & Allan, R. (1978). Analogy and abstraction strategies in synthetic grammar learning: A functionalist interpretation. *Cognition*, 6, 189-221.

Reber, A. S. & Lewis, S. (1977). Toward a theory of implicit learning: The analysis of the form and structure of a body of tacit knowledge. *Cognition*, 5, 333-361.

Reber, A. S. & Millward, R. B. (1968). Event observation in probability learning. *Journal of Experimental Psychology*, 77, 317-327.

Reber, A. S. & Millward, R. B. (1971). Even tracking in probability learning. *American Journal of Psychology*, 84, 85-99.

Reber, A. S. (1967). Implicit learning of artificial grammars. *Journal of Verbal Learning and Verbal Behavior*, 6, 317-327.

Reber, A. S. (1969). Transfer of syntactic structure in synthetic languages. *Journal of Experimental Psychology*, 81, 115-119.

Reber, A. S. (1976). Implicit learning of synthetic languages: The role of instructional set. *Journal of Experimental Psychology*: Human Learning and Memory, 2, 88-94.

Reber, A. S. (1993). *Implicit learning and tacit knowledge: An essay on the cognitive unconscious.* Oxford: Oxford University Press.

Reber, A. S. (2011). An epitaph for grammar: An abridged history. In: C. Sanz & R. P. Leow (Eds.). *Implicit and explicit language learning: Conditions, processes & knowledge in SLA and Bilingualism* (pp. 23-34). Washington, DC: Georgetown University Press.

Rebuschat, P. & Williams, J. N. (2006). Dissociating implicit and explicit learning of natural language syntax. In: R. Sun & N. Miyake (Eds.), *Proceedings of the 28th Annual Conference of the Cognitive Science Society* (pp. 2594). Mahwah, NJ: Lawrence Erlbaum.

Rebuschat, P. & Williams, J. N. (2012). Implicit and explicit knowledge in second language acquisition. *Applied Psycholinguistics*, 33(4), 829-856.

Rebuschat, P. (2008). Implicit learning of natural language syntax. *Unpublished PhD dissertation*, University of Cambridge, UK.

Rebuschat, P. (2013a). Implicit learning. In: P. Robinson (Ed.), *The Routledge encyclopedia of second language acquisition* (pp. 298-302). London: Routledge.

Rebuschat, P. (2013b). Measuring implicit and explicit knowledge in second language research. *Language Learning 63(3),* 595-626.

Rebuschat, P., Hamrick, P, Sachs, R., Riestenberg, K. & Ziegler, N. (2015). Triangulating measures of awareness: a contribution to the debate on learning without awareness. *Studies in Second Language Acquisition*.

Rebuschat, P., Hamrick, P., Sachs, R., Riestenberg, K. & Ziegler, N. (2013). Implicit and explicit knowledge of form-meaning connections: Evidence from subjective measures of awareness. In: J. M. Bergsleithner, S. N. Frota, & J. K. Yoshioka, (Eds.), *Noticing and second language acquisition: Studies in honor of Richard Schmidt* (pp. 255–275). Honolulu: University of Hawaii, National Foreign Language Resource Center.

Rebuschat, P., Hamrick, P., Sachs, R., Riestenberg, K., Ziegler, N. (in press). *Awareness, reactivity and subjective measures*.

Reed, J. & Johnson, P. (1994). Assessing implicit learning with indirect tests: Determining what is learned about sequence structure. *Journal of Experimental Psychology*: Learning, Memory, & Cognition, 20, 584-594.

Reingold, E. M. & Merikle, P. M. (1988). Using direct and indirect measures to study perception without awareness. *Perception and Psychophysics*, 44, 563-575.

Remillard, G**.** (2003). Pure perceptual-based sequence learning. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, *29*, 581-597.

Robinson, P. (1996). Learning simple and complex second language rules under implicit, incidental, rule-search & instructed conditions. *Studies in Second Language Acquisition*, 19, 27-67.

Rosa, E. & Leow, R. P. (2004). Awareness, different learning conditions & L2 development. *Applied Psycholinguistics*, 25(2), 269-292.

Rosa, E. & O'Neill, M. D. (1999). Explicitness, intake & the issue of awareness. *Studies in Second Language Acquisition*, 21(4), 511-556.

Rosenthal, D. M. (2005). *Consciousness and Mind*, Clarendon Press

Sachs, R. & Suh, B-R. (2007). Textually enhanced recasts, learner awareness & L2 outcomes in synchronous computer-mediated interaction. In: A. Mackey (Ed.), *Conversational interaction and second language acquisition: A series of empirical studies* (pp. 197-227). Oxford: Oxford University Press.

Saffran, J. R. (2003). Statistical language learning: Mechanisms and constraints. Current Directions in *Psychological Science*, 12, 110-114.

Saffran, J. R., Aslin, R. N. & Newport, E. L. (1996). Statistical learning by 8-month old infants. *Science*, 274, 1926-1928.

Saffran, J. R., Newport, E. L. & Aslin, R. N. (1996). Word segmentation: The role of distributional cues. *Journal of Memory and Language*, 35, 606-621.

Saffran J. R., Newport E. L., Aslin R. N., Tunick R. A. & Barrueco S. (1997). Incidental language learning: Listening (and Learning) out of the Corner of Your Ear. *Psychological Science*, 8 (2), pp. 101-105.

Sanz, C. & Leow, R. P. (2011). (Eds.). *Implicit and explicit language learning: Conditions, processes & knowledge in SLA and Bilingualism*. Washington, DC: Georgetown University Press.

Schmidt, R. (1990). The role of consciousness in second language learning. *Applied Linguistics*, 11, 129-158.

Schmidt, R. (1993). Awareness and second language acquisition. *Annual Review of Applied Linguistics*, 13, 206-226.

Schmidt, R. (1994). Deconstructing consciousness in search of useful definitions for applied linguistics. *AILA Review - Revue de l'AILA*, 11, 11-26.

Schmidt, R. (1995). Consciousness and foreign language learning: A tutorial on attention and awareness in learning. In: R. Schmidt (Ed.), *Attention and awareness in foreign language learning* (pp. 1-63). Honolulu, HI: University of Hawai`i, National Foreign Language Resource Center.

Schmidt, R. (2001). Attention. In: P. Robinson (Ed.), *Cognition and second language instruction* (pp. 3-32). Cambridge University Press.

Schuchard, J. & Thompson, C. K. (2014). Implicit and Explicit Learning in Individuals with Agrammatic Aphasia. *Journal of Psycholinguistic Research* 43:, pages 209-224.

Segal, E. M. & Halwes, T. G. (1966). The influence of frequency of exposure on the learning of a phrase structural grammar. *Psychonomic Science*, 4, 157-158.

Servan-Schreiber, E. & Anderson, J. R. (1990). Learning artificial grammars with competitive chunking. *Journal of Experimental Psychology*: Learning, Memory & Cognition, 16, 592-608.

Shanks, D. R. & Channon, S. (2002). Effects of a secondary task on “implicit” sequence learning: Learning or performance? *Psychological Research*, 66, 99–109.

Shanks, D. R. & St. John, M. F. (1994). Characteristics of dissociable human learning systems. *Behavioral and Brain Sciences,* 17, 367–447. Stadler, M. A. (1989). On learning complex procedural knowledge. *Journal of Experimental Psychology*: Learning, Memory & Cognition, 15, 1061–1069.

Shanks, D. R. (1995). *The psychology of associative learning*. New York: Cambridge University Press.

Shanks, D. R. (2003). Attention and awareness in ‘‘implicit’’ sequence learning. In: L. Jiménez (Ed.), Attention and implicit learning (pp. 11-42). Amsterdam: Benjamins.

Shanks, D. R. (2005). Implicit learning. In: K. Lamberts & R. Goldstone (Eds.), *Handbook of cognition* (pp. 202–220). London: Sage.

Shanks, D. R., Green, R. E. A. & Kolodny, J. A. (1994). A critical examination of the evidence for unconscious (implicit) learning. In: C. Umilta & M. Moscovitch (Eds.), *Attention and performance XV: Conscious and nonconscious information processing* (pp. 837–860). Cambridge, MA: MIT Press.

Slone, L. K., Johnson, S. P.  (2015). Infants' statistical learning: 2- and 5-month-olds' segmentation of continuous visual sequences. *Journal of Experimental Child Psychology.*

Smith, K. H. (1966). Grammatical intrusions in the free recall of structured letter pairs. *Journal of Verbal Learning and Verbal Behavior*, 5, 447-454.

Smith, J. G., Siegert, R. J., McDowall, J. &Abernethy, D. (2001). Preserved implicit learning on both the serial reaction time task and artificial grammar in patients with Parkinson's disease. *Brain and Cognition*, 45 (3), 378–391.

Spada, N. & Tomita, Y. (2010). Interactions between type of instruction and type of language feature: A meta-analysis. *Language Learning 60(2),* 263–308.

St. John, M. F. & Shanks, D. R. (1997). Implicit learning from an information-processing standpoint. In: D. C. Berry (Ed.), *How implicit is implicit learning*? (pp. 162-194). Oxford: Oxford University Press.

Stanley, W. B., Mathews, R. C., Buss, R. R. & Kotler-Cope, S. (1989). Insight without awareness: On the interaction of verbalization & practice in a simulated process control task. *Quarterly Journal of Experimental Psychology*, 41, 553-577.

Terrell, T. (1991). The role of grammar instruction in a communicative approach. *Modern Language Journal*, 75, 52–63.

Thiessen, E. D. (2007). The effect of distributional information on children's use of phonemic contrasts. *Journal of Memory and Language*. 56:16–34.

Toth, J. P. & Reingold, E. M. (1996). Beyond perception: Conceptual contributions to unconscious influences of memory. In: G. Underwood (Ed.), *Implicit cognition* (pp. 41- 84). Oxford: Oxford University Press.

Tunney, R. J. & Shanks, D. R. (2003). Subjective measures of awareness and implicit cognition. *Memory & Cognition*, 31(7), 1060-1071.

Walk, A M. and Conway, C. M. (in press). Implicit statistical learning and language acquisition: Experience-dependent constraints on learning. In: Rebuschat, Patrick (ed.), *Implicit and Explicit Learning of Languages*. 2015.

Warker, J. A. & Dell, G. S. (2006). Speech errors reflect newly learned phonotactic constraints. *Journal of Experimental Psychology: Learning, Memory & Cognition*, 32 , 387–398.

Wickens, T. D. (2002). Elementary signal detection theory. Oxford: Oxford University Press.

Williams, J. N. & Rebuschat, P. (2015). *Implicit learning and second language acquisition.* New York: Routledge.

Williams, J. N. (2004). Implicit learning of form-meaning connections. In: VanPatten, M., Williams, J. N., Rott, S. & Overstreet, S. (Eds.), *Form meaning connections in second language acquisition* (pp. 203–218). Mahwah, N. J.: Lawrence Erlbaum Associates.

Williams, J. N. (2005). Learning without awareness. *Studies in Second Language Acquisition, 27(2)*, 269-304.

Williams, J. N. (2009). Implicit learning in second language acquisition. In: Ritchie, W. C. and Tej, K. Bhatia (Eds.), *The new handbook of second language acquisition* (pp. 319-353), Emerald Group Publishing Limited.

Willingham, D. B., Nissen, M. J. & Bullemer, P. (1989). On the development of procedural knowledge. *Journal of Experimental Psychology*: *Learning, Memory, & Cognition*, 15, 1047-1060.

# Appendix

**Training Item:**

Bruce was a big bear living deep in an old forest valley. Everyone knew that Bruce was lazy and that he loved to sleep in his cave right next to hul honey pot. However, every once in a while he would get up and cross the valley walking to rel pine forest near the river and gather new honey.
As Bruce woke up on a sunny autumn morning, he decided that today would be such a day. He got up from his bed and walked out of hul cave. As he walked through the valley he spotted a herd of rabbits on the other side of a meadow. One of them started to approach Bruce. Relt rabbit was Mr. Fluffle.
“I greet you kindly dear Bruce," he said once he reached Bruce. "I expect you are walking to relt bee queen in the pine forest to ask for some honey?"
Bruce looked at hult rabbit next to him and grumbled something that could conceivably have been an affirmation.
Mr. Fluffle jumped at this, "Mrs. Fluffle has hurt one of her legs and dearly needs some healing herbs that grow next to rel river. I was about to run there myself, but I still have to gather more food for the winter."
Bruce heard the unspoken plea in Mr. Fluffle's words and while he very much disliked moving he did like Mrs. Fluffle for her honeycakes! "I shall see if I can find some on my way," he rumbled, nodded to hult hare and started walking again.

**Task 1: Cloze**

Soon he entered an old oak wood. The majestic trees grew far into      sky. After a few steps three boars appeared behind      trees directly to his right.
"Hey, what are you doing in our forest?!" one of them asked gristly, "You have to pay tribute if you want to pass."
Bruce let out a deep growl, focusing his eyes long on      boar. "You want to stop me?" he asked slowly. The boar seemed to waver for a moment but then it called, "Get him, boys!". In a quick motion no one would have expected of Bruce he struck one boar with his paw and sent it flying into      nearest tree. Then he used his snout to grab the other one by the neck. Still growling, with the boar still pinned down by his jaw he focused leader again.
"Damn, let us scram it," it cursed and took off instantly. Bruce relaxed his jaw and the other two boars took after      already distant leader.
Annoyed by the disturbance Bruce started walking toward      bee hive again. While he walked to the river he also saw some deer in the distance, but      deer took off the moment they saw him.

**Task 2: 2AFC**

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|---|---|
| **rel** | Bruce walks to rock on the other side of the valley<br>Mr. Fluffle sees warren in the hill beyond the meadow<br>The boar swears revenge and yells at mountain beyond the woods<br>The bees fly to flower field far beyond the pine wood |
| **hul** | Mrs. Fluffle kneads honey cake dough in front of her<br>Mr. Fluffle gently cradles carrot in his paws<br>Bruce clears out pinewood chest in front of him<br>The bee queen sits directly on top of hive |
| **relt** | Bruce sits in his cave and decides to visit salmon prince swimming up the river<br>Mrs. Fluffle brings some honeycakes to hedgehog living next to Bruce's cave<br>The bees fear hornet queen living beyond the woods on the mountain<br>Bruce sees falcon king flying high above him in the sky |
| **hult** | Bruce stops charging stag a split second before the impact<br>Mrs. Fluffle cuddles with newborn bunny of her sister<br>Bruce stops directly in front of Mr. Feen and greets old fox<br>Bruce gently embraces young doe. |

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# Selbstständigkeitserklärung

Hiermit versichere ich, dass ich die vorliegende schriftliche Hausarbeit (einschließlich eventuell beigefügter Zeichnungen, Kartenskizzen, Darstellungen u. ä. m.) selbständig verfasst und keine anderen als die angegebenen Quellen und Hilfsmittel benutzt habe. Alle Stellen der Arbeit, die dem Wortlaut oder dem Sinn nach anderen Werken entnommen sind, habe ich in jedem einzelnen Fall unter genauer Angabe der Quelle deutlich gekennzeichnet.

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