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Frequency Effects, Learning Conditions, and the Development of Implicit and Explicit Lexical Knowledge

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FREQUENCY EFFECTS IN LANGUAGE are robust, but they interact in complex ways with other internal and external factors. An experiment investigated such an interaction between frequency, awareness (internal), and learning conditions (external) in adult lexical development. Participants were exposed to pseudowords and images under either incidental or intentional conditions and were then given a picture-matching task with subjective measures of awareness (Rebuschat 2008). We report two primary findings: first, frequency effects in lexical development are similar for implicit and explicit knowledge, consistent with theories of SLA proposing a single memory system for implicit and explicit lexical knowledge. Second, frequency effects were larger under incidental than intentional learning conditions. Overall, the results suggest complex interactions between frequency, learning conditions, and awareness.

Decades of psycholinguistic research have shown that input frequency and the probabilistic quality of natural language impact language acquisition at all levels (see, e.g., Ellis 2002; Lieven 2010; Rebuschat and Williams 2012; Saffran 2003). Humans are sensitive to how often words, phrases, and syntactic constructions co-occur in the input. Indeed, language is rich with such statistical information. For example, in English, the probability that a noun will occur immediately after *the* is very high, while the probability that *the* is followed by an adjective is lower, and the probability that it is followed by an adverb even lower. However, humans do not develop sensitivity to such frequencies and probabilities in a vacuum. They do not simply tally frequency information. Rather, their knowledge of natural language frequencies is modulated by other factors. For example, Goldschneider and DeKeyser (2001) showed that frequency interacts with perceptual salience to predict 71 percent of the variance in second language (L2) morpheme acquisition order, which is more than frequency contributes when isolated. Likewise, frequency interacts with attentional processing. Higher frequency of surface forms makes attentional processing during learning more likely and influences the subsequent strengthening of that knowledge (Perruchet and Vinter 2002). Thus, although frequency is an independent variable in learners' input with its own characteristics, it nevertheless interacts with other variables. However, despite an increasing consensus that frequency effects are a crucial aspect of language acquisition, many questions about them remain unexplored. In the present experiment, we investigated two of these questions. The first has implications for second language acquisition (SLA) theory: Is there any relationship between implicit and explicit knowledge and input frequency? That is, are implicit and explicit knowledge subserved by mechanisms with the same or different underlying sensitivities to frequency? This question is important, as it addresses fundamental assumptions of Emergentist and neurocognitive approaches to language (Ellis 2002; Ullman 2005). The second question has implications for research methodology: Are frequency effects on learning the same or different under incidental and intentional learning conditions? In other words, does frequency impact learning differently under different learning conditions?

Before describing our investigation of these questions, we briefly review theories of frequency effects, implicit and explicit knowledge, and learning conditions. We first review measures of implicit and explicit knowledge as they are a central element of our experimental design. We then report our experiment and the relevance of our findings for SLA theory and methodology, and, briefly, other language-related fields, in particular, corpus linguistics.

Frequency, Implicit and Explicit Knowledge, and Learning Conditions

Frequency-based mechanisms, often termed statistical learning mechanisms, are often argued to underlie the development of implicit knowledge—knowledge that is unconscious and generally difficult to verbalize. Some researchers assume that implicit learning and statistical learning are the same phenomenon (Conway and Christiansen 2006; Ellis 2002, 2005; Perruchet and Pacton 2006); however, elsewhere it has been argued that frequency-driven statistical learning appears to give rise to both implicit and explicit knowledge (Hamrick and Rebuschat 2012). There is general agreement that learners do not simply count up instances of use in language (Ellis 2002). The actual processing of frequency information in learning is implicit, but the acquired knowledge is not necessarily also implicit, which is to say that implicit brain processes might result in conscious knowledge (Perruchet and Vinter 2002). Moreover, it is unclear to what extent the resulting implicit and explicit knowledge veridically reflects the frequencies processed by the learning mechanisms (Shanks 1995).

Likewise, it is not clear to what extent frequency effects are modulated by learning conditions. Many studies purporting to show the effects of frequency and other statistical information in language learning have varied in their use of incidental and intentional learning conditions. For present purposes, we consider incidental learning conditions to be those in which participants are not informed of a test or that they should be learning. Intentional learning, on the other hand, refers to informing participants of a subsequent test phase, as well as possibly telling participants to try to learn the regularity or pattern in the stimulus material.

Frequency-driven learning has been clearly demonstrated under intentional learning conditions. Yu and Smith (2007) found that adults were sensitive to word-referent co-occurrence frequencies when told to try to learn. Likewise, Kachergis, Yu, and Shiffrin (2009) found more fine-grained evidence of frequency effects in intentional word learning, with increasing frequency leading to incrementally better performance. However, other studies on frequency-based and statistical learning have relied on strictly incidental learning conditions. For example, Saragi, Nation, and Meister (1978) and Pellicer-Sánchez and Schmitt (2010) found incidental learning of novel vocabulary that appeared to be driven in part by frequency. Incidental learning based on frequency and statistical cues has been shown in other language domains as well, (e.g., Hasher et al. 1987; Saffran et al. 1997; Romberg and Saffran 2010). For example, Saffran et al. (1997) showed that children and adults were equally good at extracting words from a speech stream when the only cues to speech segmentation were probabilistic. In sum, while many studies have shown robust frequency-driven learning effects, there has been little in the way of a systematic investigation of whether incidental or intentional learning conditions constrain or promote frequency effects.

One notable exception is Kachergis, Yu, and Shiffrin (2010, experiment 2), who compared incidental and intentional cross-situational word learning using a within-subjects design in order to investigate implicit learning. Cross-situational word learning requires participants to track pseudoword-referent co-occurrence frequencies across training trials (this paradigm is explained further in the methods section below). Kachergis, Yu, and Shiffrin (2010) found that participants were able to learn some pseudoword-referent pairs under incidental conditions, but that the same participants performed much better when instructed to search for word meanings. Thus, there is some evidence that learning conditions modulate frequency-based learning. However, despite their claims to be investigating implicit learning, no measures of awareness were included—it is unclear whether the acquired knowledge was implicit or explicit. There were also no manipulations of individual pseudoword-referent pairing frequency. Therefore, the interactions between frequency, learning conditions, and awareness were not assessed.

The present study sought to investigate these gaps in the literature. Humans aquire both implicit and explicit knowledge about language, and language acquisition appears to be, at least in part, the consequence of frequency-based learning mechanisms. But it is unclear to what extent implicit and explicit knowledge reflect the statistical properties of the input. Further complicating matters is the fact that frequency-based learning effects are often reported without reference to learning conditions, making the role of frequency difficult to interpret. It is possible that the amount of learning in these studies is the result not just of frequency effects, but also of their interaction with learning conditions. Before discussing how our experiment addressed these issues, we briefly review the measures of awareness we used in order to assess the conscious status of learners' knowledge in our study.

Measuring Implicit and Explicit Knowledge

Whether the knowledge acquired during incidental learning is actually implicit is a controversial issue. Several measures of awareness have been proposed (see Dienes and Seth 2010; Rebuschat, in press), and here we review those used in the present study.

Verbal reports. A common way of distinguishing implicit and explicit knowledge is to prompt subjects to verbalize anything they might have noticed while doing the experiment (e.g., Reber 1967). Knowledge is considered to be unconscious if subjects perform above chance despite being unable to verbalize the knowledge that underlies their performance. But this operationalization has been criticized for a variety of reasons (Perruchet 2008). For one, participants may only be able to verbalize knowledge after a long exposure period. Another problem is that verbal reports are a relatively insensitive and incomplete measure of implicit and explicit knowledge. For example, subjects may not verbalize knowledge because low-confidence knowledge retrieval may be difficult.

Subjective measures. Dienes (2008) advocated the use of subjective measures in order to assess whether the knowledge acquired during Artificial Grammar Learning (AGL) tasks is implicit or explicit. One way of dissociating implicit and explicit knowledge is to collect confidence ratings (e.g., Dienes et al. 1995). In AGL tasks, for example, participants can be asked to report how confident they were for each grammaticality decision. Dienes et al. (1995) suggested two ways in which confidence judgments could index implicit knowledge. First, knowledge can be considered unconscious if participants believe they are guessing when their classification performance is, in fact, significantly above chance. This is called the guessing criterion. Second, knowledge is unconscious if participants' confidence is unrelated to their accuracy. This is known as the zero correlation criterion. Several studies have shown that performance on standard AGL tasks can result in unconscious knowledge according to these criteria (e.g., Dienes et al. 1995).

Structural knowledge and judgment knowledge. Confidence judgments have been criticized because of the type of knowledge that is assessed by this measure, especially regarding the case of natural language acquisition (Dienes 2008). Language acquisition is often considered a prime example of implicit learning. All cognitively unimpaired adults are able to discern grammatical sentences of their native language from ungrammatical ones, even though they are unable to report the underlying rule system. However, when asked how confident they are in their grammaticality decisions, most native speakers will report high confidence levels; for example, they might say, "'John bought an apple in the supermarket' is a grammatical sentence, and I am 100% confident in my decision, but I do not know what the rules are or why I am right." In these cases, confidence judgments and accuracy will be highly correlated, but does this mean that language acquisition is not an implicit learning process after all? Probably not. Dienes (2008) and Dienes and Scott (2005) proposed a convincing explanation for this phenomenon based on Rosenthal's (2005) Higher-Order Thought Theory.

Dienes argued that when participants are exposed to letter sequences in an AGL experiment, they learn the structure of the sequences. This structural knowledge can consist, for example, of knowledge of associations, exemplars, fragments, or rules. In the testing phase, participants apply their structural knowledge to construct a different type of knowledge: knowledge of whether the test items shared the same structure as the training items. Dienes labeled this judgment as knowledge. Both structural and judgment knowledge can be implicit or explicit. For example, a structural representation about letter repetition is only conscious if it is explicitly represented—in other words, if there is a corresponding higher-order thought such as "I {know/think/believe, etc.} that a letter can repeated several times." Likewise, judgment knowledge is only conscious if there is a corresponding higher-order thought (e.g., "I {know/think/believe, etc.} that this item has the same structure as the training sequences.") The guessing criterion (i.e., participants believe they are guessing, but they perform above chance) and the zero correlation criterion (i.e., confidence is unrelated to accuracy) measure the conscious status of judgment knowledge, not structural knowledge.

Moreover, Dienes and Scott (2005) posit that conscious structural knowledge leads to conscious judgment knowledge. However, if structural knowledge is unconscious, judgment knowledge could still be either conscious or unconscious, which explains why, in the case of natural language, people can be very confident in their grammaticality decisions without knowing why. Here, structural knowledge of the language is implicit while metalinguistic judgment knowledge is explicit. This leads to the phenomenology of intuition: knowing that a judgment is correct, but not knowing why. However, if both structural and judgment knowledge are implicit, the phenomenology is that of guessing. In both cases, the structural knowledge acquired during training is implicit. To assess the conscious status of both structural and judgment knowledge, source attributions can be added to the confidence ratings in the testing phase. Thus, after asking participants how confident they were in their grammaticality judgments, one also prompts the participants to report the basis of their judgments.

Method

The following experiment had two objectives. The first objective was to investigate a theoretical question: Do implicit and explicit knowledge reflect input frequency in similar ways, or do implicit and explicit knowledge reflect different sensitivities to frequency? The second objective was to address a methodological question: Are frequency effects differentially influenced by incidental and intentional learning conditions? In order to address these questions, we employed the cross-situational word learning paradigm, which has been widely used in the investigation of frequency-driven learning and statistical learning (e.g., Hamrick and Rebuschat 2012; Yu and Smith 2007; Kachergis, Yu, and Shiffrin 2010)

Participants

Thirty native speakers of English (19 women and 11 men, $M_{age} = 19.3$) were recruited from introductory linguistics classes randomly assigned to incidental or intentional learning conditions (fifteen in each group). There were no significant differences between the two groups in terms of age or number of other languages spoken, *p*s > 0.05.

Stimuli

An artificial lexicon consisting of twenty-seven auditory pseudowords was created for this experiment. All pseudowords were bisyllabic, stressed on the first syllable, and obeyed English phonotactics. The pseudowords were read aloud by a female native speaker of English and digitally recorded by means of sound processing software (Audacity, version 1.2.4). Each pseudoword was then matched with one or more black-and-white drawings from the International Picture-Naming Project website (Szekely et al. 2004).

The lexicon was divided into twelve target and fifteen filler items. All filler items were unambiguous and only occurred once each in the input during the exposure phase. The target items were subdivided into six lexically ambiguous pseudowords (i.e., one word with three matching referents) and six lexically unambiguous pseudowords (i.e., one word with one matching referent). All target words were manipulated in terms of their pseudoword-referent co-occurrence frequencies. Some pseudowords co-occurred with their matching referents six times, other pseudowords co-occurred with their appropriate referents four times, and others co-occurred with their appropriate referents twice (see table 9.1). For example, the pseudoword *houger* occurred twelve times: six times with an elephant, four times with a glass, and two times with a pear.

Table 9.1.
Ambiguous and unambiguous target items and their referents

Pseudoword	Referents (Co-Occurrence Frequency)		
dobez	backpack (6),	arrow (4),	bathtub (2)
paylig	wheelchair (6),	towel (4),	bandage (2)
femod	bench (6),	thumb (4),	bridge (2)
Whoma	comb (6),	crib (4),	fan (2)
Houger	elephant (6),	glass (4),	pear (2)
Jillug	ladder (6),	leaf (4),	mixer (2)
Keemuth	mop (6)		
Nengee	panda (6)		
Zomthos	radio (4)		
Loga	stethoscope (4)		
Shrama	robot (2)		
Thueek	tank (2)		

Exposure phase. In the exposure phase, subjects in both conditions were presented with the same fifty-seven trials. In each trial, a fixation cross was first displayed for two seconds. Then two images were displayed on the screen at the same time, one on the left side and the other on the right side (see figure 9.1). The two images were displayed for six seconds. While the images were on display, two pseudowords were played once each. For example, subjects might see an image of a panda on the left and an image of a glass on the right, while hearing first the pseudoword *houger*, followed by the pseudoword *nengee*. Importantly, the presentation order of the pseudowords was not related to the location of the images on the screen. That is, each word could refer either to the image on the left or to the image on the right. The only way for participants to learn the artificial vocabulary was to use the pseudoword-object co-occurrence frequencies across trials. The order of trials was randomized for each participant.

Procedure

The experiment was presented on a PC with a 15.6-inch screen using Microsoft Power Point 2007 running a randomization macro. Instructions were displayed in black text (Arial font sizes 20–24) on a white background. Pseudowords were played through headphones. The experiment consisted of an exposure phase and a testing phase. The content of the exposure and testing phases was the same for both groups. The groups only differed in how they interacted with the fifty-seven exposure trials.

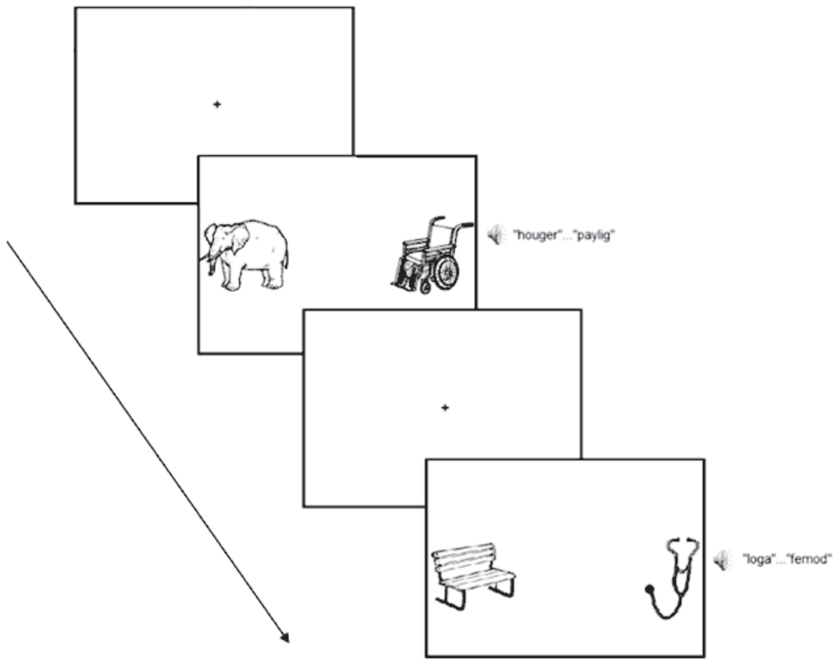

Figure 9.1 Simple Screenshot Sequence from the Exposure Phase

Exposure phase. Subjects in the intentional learning condition (n = 15) were told that they were participating in a word-learning experiment and were instructed to "learn the meanings of the words." They were also told that they would be tested afterwards. In contrast, subjects in the incidental learning condition (n = 15) were not informed about the true purpose of the experiment, nor did they know that they would be tested after the exposure phase. Moreover, participants were given a deliberately misleading task. They were told that the objective of the study was to investigate how people with different language experience perceive and categorize objects. Their task during the exposure phase was to indicate how many objects on each slide were animate. There were three possible responses per trial (zero, one, or two animate objects) and participants were instructed to enter 0, 1, or 2 on their keypads. This task was made more difficult by the presence of pictures that were not easily classifiable as animate or inanimate (e.g., a thumb, a leaf). They were informed that they would have to do the task while hearing "nonsense" words through their headphones.

In sum, all experimental subjects were exposed to the same fifty-seven trials. The key difference between subjects in the intentional and incidental groups is how they interacted with the stimuli. Subjects in the former group were instructed to learn the meanings of words, whereas subjects in the latter group were asked to perform an irrelevant task and to treat the auditory pseudowords as nonsense.

Test phase. After the exposure phase, all participants completed a four-alternative forced-choice (4AFC) picture matching task. The 4AFC task consisted of thirty trials. In each trial, participants were presented with four pictures, one in each corner of the screen, and a spoken pseudoword. Their task was to select the appropriate referent as quickly and accurately as possible.

For each trial, the screen contained one correct referent and three foils. Each picture was numbered and participants indicated the best match by writing down their answers on an answer sheet. Additionally, subjects were asked to report how confident they were in their decision and what the basis of their decision was. Subjects were asked to place their confidence on a continuous scale, ranging from 50 percent (complete guess) to 100 percent (complete certainty). We emphasized that subjects should only use 50 percent when they believed to be truly guessing—in other words, they might as well have flipped a coin. In the case of the source attributions, there were three response options: guess, intuition, and memory. The guess category indicated that subjects believed the classification decision to be based on a true guess. The intuition category indicated that they were somewhat confident in their decision but did not know why it was right—they simply had a "gut feeling." The memory category indicated that the judgment was based on the recollection of pseudoword-referent mappings from the exposure phase. All participants were provided with these definitions before starting the testing phase.

At the end of the test phase, all subjects completed a debriefing questionnaire which asked them to report if they had learned any of the pseudoword-referent mappings during exposure, whether or not they had used any specific learning strategies, and, if so, what kind of strategies.

Results

Performance on the 4AFC task served as the measure of learning. Awareness was measured by means of confidence ratings and source attributions.

Four-Alternative Forced-Choice Task

The analysis of the 4AFC task showed that both the incidental group (*M* = 44.4%, *SD* = 7.5%) and the intentional group (*M* = 73.3%, *SD* 10.7%) performed significantly above chance (chance = 25%), $t_{incidental}(14) = 9.99$, $p < 0.05$, $t_{intentional}(14) = 17.53$, $p < 0.05$. Performance in the intentional group was also significantly above that of the incidental group, $t(28) = 8.54$, $p < 0.001$. The results indicate that there was a clear learning effect for both groups, with a greater learning effect under intentional learning conditions.

Measuring the Conscious Status of the Acquired Knowledge

Confidence ratings. The average confidence level was 61.3 percent (*SD* = 7.2%) in the incidental group and 80.6 percent (*SD* = 6.3%) in the intentional group. The difference was significant: $t(28) = 7.79$, $p < 0.05$. Further analysis showed that accuracy and confidence were significantly correlated in the intentional group ($r = 0.77$, $p < 0.05$), but not in the incidental group ($r = 0.45$, $p > 0.05$). When intentional learners were confident in their decision, they tended to be accurate. This suggests that subjects in the intentional group had acquired conscious judgment knowledge; these participants were partially aware that they had acquired some knowledge during the exposure phase. In contrast, subjects in the incidental group were not consistently aware of having acquired knowledge, despite the fact that their performance on the 4AFC task clearly indicates that they did. The zero correlation criterion was thus met in the case of the incidental group.

We then analyzed all classification decisions for which subjects gave a 50 percent rating, meaning that they believed to have guessed when deciding on the appropriate referent for the pseudoword. Incidental participants indicated that they were guessing on 44.2 percent of test trials, while intentional participants indicated that they were guessing on only 9.9 percent of trials. A one-sample *t*-test indicated that participants' accuracy on the test when they gave a 50 percent confidence rating was 33.5 percent (*SD* = 17.2%), which trended toward significance, $t(14) = 1.92$, $p = 0.07$. In the case of the intentional group, when subjects gave a confidence rating of 50 percent, their mean classification performance was 44.1percent (*SD* = 18.9%), which was significantly above chance: $t(14) = 2.95$, $p < 0.05$. Thus, the guessing criterion for unconscious judgment knowledge was satisfied in the intentional group, while there was trending evidence for unconscious judgment knowledge in the incidental group.

The confidence ratings indicate that the incidental group was largely unaware of having acquired knowledge during the exposure phase. In the case of the intentional group, subjects were clearly aware of having acquired knowledge (see correlation between confidence and accuracy), though some of their judgment knowledge did remain unconscious (as indicated by the guessing criterion).

Source attributions. In terms of proportion, the incidental group most frequently believed their classification decisions to be based on a guess or intuition (86 percent of judgments). The memory category was selected least frequently (only 14 percent of all judgments). That is, during the 4AFC task, subjects in the incidental group generally based their decisions on the more implicit categories. In the case of the intentional group, the memory category was selected most frequently (61 percent of judgments), followed by guessing and intuition. In terms of accuracy, the analysis showed that the incidental group scored highest when reporting that their classification was based on memory, followed by the intuition and guess categories (table 9.2). The same pattern was observed in the intentional group; these subjects were most accurate when attributing their classification decision to memory. They were, however, considerably more accurate, performing close to 90percent accuracy.

Repeated measures ANOVAs with Source Attribution (three levels: guess, memory, and intuition) as a within subjects factor and accuracy as the dependent variable revealed significant effects of Source Attribution in both the incidental group [$F(2, 14) = 8.25, p < 0.05$] and the intentional group [$F(2, 14) = 5.59, p < 0.05$]. In the case of the incidental group, the difference between decisions based on guessing and decisions based on intuition was significant ($p < 0.05$), as was the difference between decisions based on guessing and those based on memory ($p < 0.05$). In the intentional group, the differences between decisions based on guessing and intuition, guessing and memory, and intuition and memory were all significant ($p < 0.05$).

Interestingly, subjects in both groups performed significantly above chance across categories, regardless of whether they attributed their decision to guessing, intuition, or memory. The guessing criterion was therefore satisfied in both groups: when subjects believed the source of their judgment to be a guess, their actual classification performance suggests that they had acquired the knowledge to make that decision. This suggests that subjects in both groups acquired at least some unconscious structural knowledge. Table 2 shows the classification performance for the different attributions.

Verbal reports. Analysis of the verbal reports showed that only learners in the intentional condition became aware of many pseudoword-referent pairs and were able to name a few. When prompted for strategies, the most commonly reported strategies were repeating the pseudowords, making a link between pseudowords and prior knowledge (e.g., “that sounded like something in French”), and hypothesis testing. In contrast, subjects in the incidental group reported deliberately trying to block out the pseudowords. Indeed, many interpreted the pseudowords to be a distraction and consequently tried to ignore them.

Frequency Effects and Interactions

To investigate the effects of frequency and ambiguity on learning outcomes, a 2×2×3 mixed design ANOVA was performed with group (two levels: incidental and intentional) as a between-subjects variable, frequency (three levels: high, mid, and low), and ambiguity (two levels: ambiguous and unambiguous) as within-subjects variables. Accuracy on the 4AFC was the dependent variable. The ANOVA revealed

Table 9.2.
Accuracy and proportions (%) across source attributions

		Guess	Intuition	Memory
Incidental	Accuracy	35.8*	48.5**	61.4**
	Proportion	44.2	41.7	14.1
Intentional	Accuracy	54.2**	61.9**	88.9**
	Proportion	23.2	27.9	48.9

Significantly different from chance (25%): *$p < .01$, **$p < .001$

a significant effect of group [$F(1, 28) = 53.02$, $p < 0.001$, partial $\eta^2 = 0.65$], which simply replicated the earlier finding of a significant difference in accuracy between the two groups. There was no effect of ambiguity ($p > 0.05$), which indicated that ambiguity alone was not a significant factor in participants' accuracy. There was an effect of frequency: $F(2, 28) = 17.06$, $p < 0.001$, partial $\eta^2 = 0.38$. This indicates that input frequency influenced accuracy at test (figure 9.2). Finally, a significant interaction was found between group, ambiguity, and frequency [$F(2, 28) = 3.56$, $p < 0.05$, $\eta^2 = 0.11$], which indicates that participants in the incidental and intentional conditions were differentially influenced by frequency and ambiguity combined.

Further investigations of frequency effects were conducted on each group separately (see figure 9.2). There was a significant effect of frequency on the incidental group [$F(2, 28) = 12.52$, $p < 0.001$], and on the intentional group, (Greenhouse-Geisser corrected) [$F(1.38, 19.42) = 5.86$, $p < 0.05$]. To investigate the effect size for frequency in the incidental and intentional groups, we conducted correlation analyses between accuracy on the 4AFC task and input frequencies for the test pseudowords. There were significant relationships between accuracy and frequency for participants

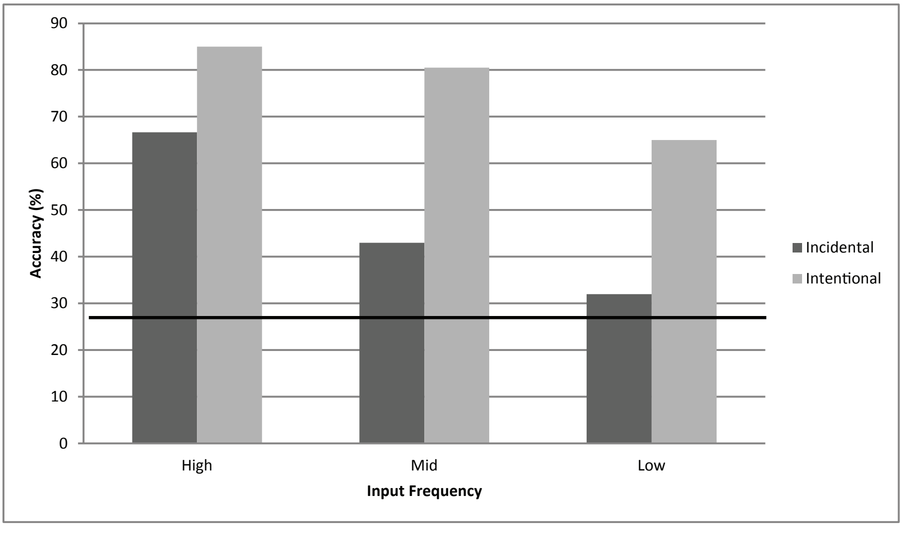

Figure 9.2 Accuracy at Test by Input Frequency When Using Implict and Explicit Knowledge

in the incidental condition ($\rho = 0.51$, $p < 0.01$) and intentional condition ($\rho = 0.26$, $p < 0.05$). Thus, the effect size of frequency on accuracy at test was larger for the incidental group than the intentional group.

We also wondered to what extent the implicit and explicit knowledge that participants developed was sensitive to input frequency. Correlation coefficients were computed between participants' accuracy when using implicit or explicit knowledge at test and input frequency. There were significant relationships between accuracy and frequency both when participants used implicit knowledge ($\rho = 0.45$, $p < 0.01$) and explicit knowledge ($\rho = 0.46$, $p < 0.05$).

Discussion

Results of the present experiment show that adult learners can learn pseudoword-referent mappings using co-occurrence frequencies under both incidental and intentional learning conditions. The results also show that adult learners can acquire implicit and explicit lexical knowledge. In terms of our research questions, our first question asked if implicit and explicit knowledge differentially reflect input frequency. The current evidence suggests that the answer is no, at least in the case of lexical knowledge. Participants showed frequency effects equally whether using implicit or explicit knowledge. This finding fits the view that frequency effects are ubiquitous and not restricted to implicit knowledge (Ellis 2002; Hamrick and Rebuschat 2012; Perruchet and Vinter 2002). More importantly for theories of SLA, these results are consistent with single-mechanism views of language learning, which posit that implicit and explicit knowledge stem from a single underlying memory system (e.g., Shanks 1995). However, the results are also consistent with the dual-mechanism view in the declarative/procedural model of language (Ullman 2005), which posits that both implicit and explicit lexical knowledge are supported by declarative memory. Our present results do not allow us to make further distinctions between these memory-based models, but this may prove to be an important avenue for further research. At the least, our results are consistent with theories of L2 vocabulary acquisition involving a common memory system that subserves both implicit and explicit lexical knowledge.

Our second question asked if frequency effects were different in incidental and intentional learning conditions. Our results suggest that the answer is yes. Accuracy levels of incidental learners showed larger frequency effects than accuracy levels of intentional learners, but intentional learners had higher overall accuracy. Thus, we make the following interpretation: frequency-based intentional learning results in significantly higher accuracy, but frequency-based incidental learning results in accuracy more veridically related to input frequency. Therefore, incidental and intentional learning are both sensitive to frequency; however, increased sensitivity does not entail increased accuracy. This finding is methodologically important because it demonstrates that learning conditions constrain frequency effects in different ways. Also, this finding is consistent with that of Kachergis, Yu, and Shiffrin (2010) and many others who have found that intentional learning conditions often result in more robust learning than incidental learning conditions (e.g., Rebuschat 2008).

Consequently, future research on frequency effects should indicate clearly the learning conditions under which participants are exposed to their input and consider the possibility that their results may not stem from frequency effects alone, but also from the learning conditions themselves. One likely solution would be for researchers to use different exposure conditions in order to assess the learning process. It should be noted that another possible explanation for the results comes from the fact that intentional learning participants performed so well that there might have been some ceiling effects. High accuracy would reduce the variation needed to find larger correlations. Teasing apart these explanations remains an issue for future research.

Finally, this study also constitutes another demonstration of the usefulness of subjective measures of awareness (cf. Rebuschat 2008, in press). Although verbal reports provided important insights into learners' thought processes and to their general levels of awareness, they would not have been fine-grained enough to permit detailed analysis of the relationship between frequency effects and implicit and explicit knowledge. Since the subjective measures provided a trial-by-trial indication of the conscious status of learners' knowledge, we were able to assess the relationship between frequency and awareness with more precision. We recommend the use of subjective measures in conjunction with other measures of awareness any time researchers are considering looking for specific relationships between test item performance, awareness, and other factors.

Conclusion

To summarize, our experiment yielded two important results, the first theoretical and the second methodological. First, frequency effects in adult language learning are not limited to implicit knowledge, but also are evident in explicit knowledge. This finding supports theories of SLA that assume a common underlying memory system for implicit and explicit lexical knowledge. Second, we showed that the ubiquity of frequency effects does not necessarily lead to the same learning results. That is, the extent to which learners develop and mirror their input is largely a result of the interaction between frequency and their learning conditions. Thus, researchers should take into account the role of task instructions in modulating learning effects. Finally, our results have implications for other areas of linguistics, such as corpus linguistics. For example, if frequency-driven learning interacts with other mechanisms and learning conditions, then researchers designing corpus-based language models may want to include analogous mechanisms in their models. Likewise, our findings are consistent with researchers working on exemplar-based approaches to variation who argue that frequency effects on mental representation are mediated by other cognitive and contextual factors. In sum, the role of frequency in language learning is mediated by learning conditions, and it is important for researchers to carefully consider this issue when conducting future investigations on frequency and language.

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