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Table of Contents

List of Tables

Abstract

Convergence Theory (CT) suggests that morphological effects are an emergent product of the convergence of orthographic, phonological, and semantic codes. At its core, CT attempts to capture the quasi-regularities ubiquitous in "morphological" phenomena. Consistent with the CT framework, recent research with adults has demonstrated that the magnitude of priming for pairs such as, *teacher-teach*, is moderated by the degree of semantic and phonological overlap between the prime and the target. An additional factor that seems central to "morphological" processes is productivity. Productivity is central to theories about the development of different morphemes and may affect processing speed for complex words. The purpose of the current project was to look at certain productive and nonproductive (less productive) affixes and how they affect the speed of processing for complex English words. The role of productivity in priming suffixed English words was examined using a lexical decision paradigm. The first study focused on the agentive morphemes *–man, -er, -ian,* and *–ist* which vary in productivity; -er and –man are highly productive whereas –ist and –ian are not. The second study focused on the adjectival morphemes *–y, -ish,* and *–ous which also vary in productivity; -y is very productive whereas –ish and –ous are less productive.* Although the results of both experiments did not support the specific prediction that more productive suffixes would prime more, the results were consistent with the general hypothesis that suffixes with different degrees of productivity would produce graded priming effects.

Degree of Productivity Differentially Affects Priming of Suffixed Words in English

Inflectional morphology has been at the center of a long-standing debate concerning how morphologically complex words are represented. Rules have been used to capture the productive aspect of our generative language capacities and it is the productivity of rules that make them so powerful and useful in a domain where there is considerable regularity[1]. At the no-rules end of the extreme are those that argue that complex words are stored as "gestalt" forms (whole words) (Butterworth, 1983). At the all-rules end are those who suggest that complex words are stored according to their stems with appropriate affixes added according to rules (Taft & Forster, 1975). However, most models draw a line somewhere in between, suggesting both the use of rules and whole word memory (Marslen-Wilson, Tyler, Waksler, & Older, 1994). Interestingly, the very notion of a complex word presupposes that it derives from more primitive constituents (i.e. morphemes) and, consequently, morphemes are defined as the "minimal meaning bearing units" i.e. the foundational semantic building blocks. It is these building blocks that must be used (via rules) in order to form complex words. For a canonical example, the word *cars* is considered to be composed of the morphemes *car* (a vehicle for transportation) and 's' (the pluralization of a word). *Cars* would constitute a complex word that is produced by the application of a rule: add 's' to a singular noun to make it plural. In

[1] If morphology is also quasi-regular as has been argued for by others (Bybee, 1985; Harm & Seidenberg, 1999; Plaut, Mclelland, Seidenberg, & Patterson, 1996; Seidenberg & McClelland, 1989), then there ought to be degrees of productivity to capture that quasi-regularity. More on this below.

rule-based accounts, recognition of complex words proceeds via some sort of decomposition process of the word into its morphemic constituents. Simple words that have no constituents (e.g. *truck*), and some very high frequency complex words (e.g. *computer*), are simply retrieved from memory.

Regular[2] and irregular forms can certainly be identified, but whether that qualitative distinction is psychologically real or not is one of the central issues in the debate. Some of the earliest and strongest evidence for a rule interpretation of regular inflection came from within the developmental approach (Berko, 1958, Ervin, 1964) and acquisition studies have proved to be a rich resource for both constraints and insights about the nature of morphology itself (Clark, 1993; Clark & Berman, 1984; Golinkoff, Hirsh-Pasek, Cauley, & Gordon, 1987; Hirsh-Pasek & Golinkoff, 1996a, 1996b).

In her now seminal Wug Test, Berko (1958) provided compelling evidence that complex words are formed from the composition of morphemes plus rules. In this study, Berko showed young children pictures followed by prompts that required the child to create new complex words such as *wugs*. The conclusion that the child was implementing a rule (add 's' to make a singular noun plural) was based on the reasoning that because the child had never heard these words before they must possess morphological rules for the creation of new words. Importantly, it seems that the Wug Test only demonstrates that word formation is productive and how that

[2] Bauer (2001) has noted 4 different meanings of the word 'regular' as used in discussions of morphological processes. In the psycholinguistic literature, 'regular' seems to mean 'freely generalizable' and that is the notion I will be intending.

productivity comes about is open for debate. Nonetheless, this study provided some of the first empirical confirmation of morphological rules.

Another major empirical phenomena seeming to support the rule proposal was the observation that children sometimes regularize irregular verbs, for example, *goed* or *felled* (Ervin, 1964). This point in a child's development is the second stage in a three-part sequence that is more generally described as a U-shaped learning curve. In stage one children use both inflections correctly, in stage two they over-regularize, and, in stage three they again produce correct behavior. The reasoning behind over-regularization in stage two parallels that of the Wug Test in that children do not hear these words from adults and so must be making use of a rule.

Two developments from within the morphology debate cast doubt on the rule-interpretation: 1) Connectionist models can simulate all three stages[3] (Rumelhart & McClelland, 1986) and; 2) regularization is not a robust phenomena – only 2.5% of irregular English tokens[4] are regularized (Marcus et al., 1992)[5]. There is a third consideration, outside of the morphology debate proper, that as U-shaped functions appear in many other domains[6] outside of word learning, the argument that they

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[3] While the fact of simulating u-shaped behavior is important in its own right, this model required what seems to be a false assumption about the nature of regularized input. Specifically, that the onset of regularization is accompanied by a sharp increase in the input of regular past-tense formations (Bybee, 1995).

[4] Tokens are instances of a type. For example, the word "wolf" would constitute a type different from "pig", but both would have multiple tokens in the story of the three pigs.

[5] However, rather than interpreting this finding as casting doubt on the use of rules, Marcus et. al. account for the paucity of over-regularization with a strong blocking device that suppresses it.

[6] Dynamical systems models have been used to explain at U-shaped behavior in other areas as well: the "stepping reflex" (Thelen & Smith, 1994), the "AnotB error

support a strictly rule learning account of morphology has become increasingly tenuous. Gershkoff-Stowe and Thelen (2004) interpret U-shaped learning as a special case of the non-linearities that are involved in all developmental processes. The point is that the phenomena of U-shaped learning (in any domain) can be understood as continuous change "in the collective dynamics of multiple, contingent processes [p. 11]" rather than the product of a qualitatively new process (the regularization rule) that involves some sort of inhibition or blocking.

As is already evident from the discussion above, past tense inflection became a major focal point for research in morphology. The historical consequence of Berko and Ervin's studies of productivity was the subsequent entrenchment of rule-based theories of morphology in the field of psycholinguistics. That is, because rules are the productive engines for our generative language capacities it is the productive aspect of rules that motivated their use in theorizing.

Since regular inflections such as *walked* are fully predictable, many theorists argued that they are computed by a rule "add *-d* to the verb stem". In contrast, irregular verb forms are unpredictable (e.g. *hit-hit, sing-sang, string-strung, feel-felt*) and must be individually memorized. However, simple "rule-rote" theories proved to be inadequate for several reasons (Pinker, 1991, Pinker & Ullman, 2002). First, many irregular verb forms constitute sub-regularities (e.g. *sing-sang, ring-rang, spring-sprang*) that preserve much of the phonological stem and are predictable within that family. Second, an irregular pattern involving a vowel change is typically seen

(Thelen, Schoner, Scheier, Smith, 2001), spatial working memory (Schutte & Spencer, 2002) within a family of phonetically similar items (e.g. *sing-sang, ring-rang*). Finally, irregular pairs can sometimes be extended to new forms on the basis of similarities to existing forms (e.g. *ting-tang*).

Pinker argues that ad hoc attempts to accommodate sub-regular verbs by making use of additional rules (e.g. change 'i' to 'u'), by analogy to regular verbs, does not work. Such an attempt would indeed resolve the first of our problems above, preserving the similarity between verb stems and their past tense forms (e.g. *sting-stung, string-strung*); but, if these sub-regular verbs are simply partitioned into lists with corresponding rules, then the similarity among the words and people's tendency to generalize irregular forms is left unexplained. Alternatively, if a pattern is extracted from these sub-regular verbs (*spring-sprang, ring-rang*, show a pattern of replacing the 'i' with an 'a' when it comes after a consonant cluster and precedes *-ng*) to demarcate the verbs to which the rule will apply, then there will be both misapplications (*bring-brang* instead of *brought, fling- flang* instead of *flung*) and failures to apply (*begin-began, swim-swam, begin* and *swim* require the vowel change but do not satisfy the rule).

Pinker points out that these sub-regular rules fail because the pattern of similarity to be accounted for is one of family resemblance rather than necessary or sufficient conditions. He proposes that the solution to a strictly rule governed system is to restrict the use of rules to the arbitrary lists that constitute regular verbs and make use of connectionist methods to account for these families of irregular verbs. However, while Pinker seems to have recognized the importance of adopting a lexical system with connectionist-like properties, he has failed to explain "... why many of the exceptions share properties with regular past-tense forms and offers no way to exploit the regular mapping in forming past tenses of these exceptions" (McClelland & Patterson, 2002, p. 464). Importantly, despite there being a number of variations on such "rule-association" hybrid models, all are committed to a categorical distinction between morphologically complex and morphologically simple forms (for those words that decompose into elements and those that do not).

Much of the morphology debate has been concerned with the use of inflectional morphemes (e.g. past tense, pluralization). Clark was one of the first researchers to focus on derivational morphology and its acquisition in children. Clark and Hecht (1982) used an elicitation procedure to test different agentive and instrumental suffixes. Children were asked to help find names for people and machines that preformed some action. For example, "I've got a picture here of someone who burns things. What could we call someone who burns things? Someone who burns things is a ____". With age, children's choices began to converge with adult preferences. Adults favor the suffix –er (*burner, digger, cutter*) and it was used more frequently as the child's age increased. Younger children relied more heavily on compound nouns for agents and used established words more often with instruments. The established word was typically related to the action denoted by the verb (*spade* for *dig* or *knife* for *cut*).

In another study involving a memory task, Clark and Cohen (1984; as cited in Clark, 1993) demonstrated that children (4 and 5) often misremembered complex words by substituting the more productive *–er* in place of the less productive *–ist* and

–ian. The point here is that, all things being equal, children will prefer *–er* because it is the more productive of the agentive suffixes.

Clark (1993) summarizes the developmental pattern present in the use of derivational morphemes associated with an understanding of agents and instruments. She describes a trajectory in which children first discover the agentive power of compounds (i.e. *–man* is used productively to form multiple agentive compound words, rat**man** (a lab scientist), fix**man** (a mechanic)). Next in order of acquisition is the agentive use of *-er* (e.g. dart**er** is someone who plays darts) followed by the instrumental use of *-er* (e.g. a press**er** is a button that has to be pressed to allow water to come out). Finally, the use of *-ist* and *-ian* appear in the child's repertoire for words such as pianist and magician. Note that *-ist* and *-ian* are not only less frequently used in English but that they often distort the stem of the word from which they derive (i.e. *piano* and *magic*).

Clark (1993) argues that a number of principles operate to constrain the acquisition of morphology in children. Importantly, Clark suggests that these principles do not operate in isolation from each other but rather that they interact to produce their effects on development. Of relevance to the current discussion are the following four principles:

Clark's first principle is that of Semantic Transparency: words are semantically transparent when a single meaning corresponds to only one sound pattern[7] (e.g. *-man*) and the meaning of the whole is accessible from the meaning of

[7] Though Clark points out that given children's tolerance for homonyms (one form to many meanings) it cannot be the one-to-one mapping that is crucial but rather the use

the roots and affixes (e.g. *magic-man*). Importantly, what is considered transparent changes as children develop; that is, it is a dynamic factor in acquisition.

The second principle is Formal Simplicity[8]: simpler forms[9] are those in which there is little change in the stem of the derived word (i.e. *baker* derived from *bake* is simpler than *magician* derived from *magic* because in the latter the stem changes more). Transparency and simplicity often go together but their dependence is asymmetrical: what is transparent is not necessarily simple but what is simple is necessarily transparent.

Their third principle is Productivity: productive word formation devices are those devices, with the appropriate meaning, that the speaker prefers in the coining of new words (e.g. *-er* is a preferred device for the coining of agents).

Finally, the principle of Contrast: contrast indicates that the use of a different word implies a difference in meaning.

One of the major motivations for the renewed interest in analogy models (connectionism in particular) was a growing appreciation for the probabilistic information present in the input and the related question of whether developmental trajectories reflect differences in the frequency of particular word types in the parental

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of contrast. Contrast: people choose words and in choosing a word, x, a person does not choose another word, y. Since x does not equal y, x must contrast with y in some way.

[8] Clark uses the term simplicity for what I will be calling phonological transparency.

[9] Simplicity of form is relative to the topology of the language being acquired and it seems that children adapt to those topological characteristics that are present in the language they learn first. This means that there may be little absolute assessment of simplicity across languages (perhaps limited to no change is simpler than some change) in which case simplicity must be determined relative to the acquired language itself.

input. Analysis of the roughly 28,000 words in the parental input corpus of the Childes Database revealed just over 1200 of them ending in *-er*, 124 ending in *-man*, 47 ending in *-ian* and 45 in *–ist* (Gonnerman, 2005). However many of these words may possess one of the above endings in an accidental sense (e.g. *sister, human, martian, fist*) in that they do not contribute additional information for the listener. Further, these numbers represent type, not token frequencies. Table 1 (from Gonnerman, 2005) displays the token frequencies of words ending in the four suffixes of interest and the percentage of those that are derived (*baker* is derived from *bake* versus *sister* which is not derived from a base).

The roughly 5300 word tokens in Table 1 reflect a representative sample from the Childes Database of the input available to children. Notice that *–er* totally dominates in terms of token frequency but that only half of these are derived words and of those only a third are for agents (*-er* is a homonym with multiple meanings). These data further the explanation for why the highly productive agentive *–er* is acquired after the less productive *–man* (*-man* has a single meaning); *–ian* also show a relatively small proportion of derived words whereas *—man* and *–ist* show similar token frequencies to *–ian* but are over twice as likely to be of a derived form. These token frequency distributions are important because children must be exposed to a sufficient number of word-structures if they are to become able to isolate and store the relevant patterns.

These differences in the token frequency patterns of particular suffixes along with an interactive view of Clark's principles can be used to provide a more complete picture of morphological development. Both semantic and phonological transparency can help explain the primacy of compound nouns over the suffixation of –er. Children learn *-man* before *–er* because it is a stand-alone word and it's meaning is more transparent; that is, the same *-er* form offers multiple meanings (e.g. agentive, instrumental, comparative) and in so doing violates the principle of contrast. Further, bare roots in compounds are phonologically simpler than root-affix or compound-affix combinations. Phonological transparency and productivity explain the subsequent trajectory of the other agentive morphemes *–ist* and *–ian*. Both endings distort their stems (*magician* from *magic* and *piano* from *pianist*) and are less productive than *–er*.

Convergence Theory and Connectionist Models

Convergence Theory (Seidenberg & Gonnerman, 2000) denies the ontological reality of "morphological" representations. Instead, "morphological" effects are argued to be an emergent product of a convergence between phonological and semantic codes. It would be advantageous to implement this hypothesis in a computational model because one could determine explicitly what resources the network has at its disposal. If no "morphological" representations are provided to the network but it is able to adequately model "morphological" phenomena, then such a model would demonstrate (at minimum) that explicit morphological representations are unnecessary. That is, the realization of such a model would constitute an existence proof that "morphological" effects can emerge from a learned relationship between phonological and semantic codes. Of relevance to the current project, once trained, a network could be used to look at its preferences for certain formation processes over others and determine if those preferences corresponded to the processes that are considered most productive in adults.

Connectionist principles are helpful in developing explicit models for frameworks that do not subscribe to some sort of rule-based account involving a categorical distinction between complex and simple words with the morpheme as a basic unit. Importantly though, the debate surrounding morphology itself is broader than connectionism and is semi-independent of that perspective. Connectionism can be seen as part of a family of frameworks[10] that share in their rejection of traditional rule-based/decomposition accounts and that endorse the proposal of a single mechanism that is sensitive to type and token frequency information; nevertheless, connectionist networks also have idiosyncratic details that need not be shared by other members in the family.

The Network Model proposed by Bybee (Bybee & Slobin, 1982) is a case in point[11]. The Network Model (NM) converges with connectionist models in many respects but also diverges in important ways. For example, in a connectionist network the relevant token frequency information is of the mapping between base and derived form; in contrast, for the NM, the relevant token information is the frequency of the derived form itself (Bybee, 1995). For some situations this difference may not be of any concern but it is a real difference that has potentially important

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[10] This family is probably best characterized as the class of models subsumed by the analogical orientation.

[11] In fact, Rumelhart and McClelland (1986) based their original simulation on this work (Bybee & McClelland, 2005).

implications[12] (Bybee, 1995). Convergence theory seems to fall somewhere in between. It is not synonymous with connectionism but has far deeper affinities with it than does the NM. In particular, it draws very heavily on connectionist ideas about emergence (Seidenberg & Gonnerman, 2000) and has been explicitly implemented in connectionist networks (Plaut & Gonnerman, 2000). Further, Gonnerman, Seidenberg and Andersen (in-press) suggest that their findings that, "morphological" effects are the result of a convergence between semantic and phonological factors, can be understood in connectionist terms. The current point to be made is simply that: the issues involved in the morphology debate are semi-independent of those that concern connectionist networks and that connectionist principles can be used to inform theories without those theories subscribing to connectionism proper.

While both traditional theories and the convergence account acknowledge that "morphological" effects exist, Plaut and Gonnerman (2000) suggest five points of departure. First, the convergence theory denies the existence of "discrete" morphemes. Morphological structure is emergent in the statistical regularities that hold across orthographic, phonological, and semantic information. Second, the same mechanisms that govern morphological structure operate on the other lexical codes, such as orthography, semantics, and phonology. Morphology is not an independent module governed by its own domain-specific rules. Third, componentiality comes in degrees, allowing networks to capture both the complete and partial regularities

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[12] For example, it seems to be the case that the higher the frequency of the derived form the weaker the mapping between it and its base, but high frequency irregulars are resistant to regularization and this makes little sense if connectionist models require a strong mapping to avoid regularization (Bybee, 1995).

present in the input. Fourth, morphological structure is not "something" above and beyond orthographic, phonological and semantic structures but rather emerges from their confluence. Fifth, the theory is not derivational. Complex words are not the product of simple words unified by rules.

Looking at English words in more detail can provide a clearer picture of morphological structure. Because of too coarse and restricted an analysis, traditional decomposition accounts proposed an ontologically real distinction between regular and exception words. However a closer look at the language, one with sufficient depth and breadth, provides a different and more complete picture. Morphological structure is clearly graded with the canonical cases reinterpreted as constituting two ends of a continuum. Accounting for this graded ontology follows naturally from the convergence model in which morphological structure emerges from the confluence of phonological and semantic codes.

Connectionist models are inherently well suited to the modeling of quasi-regular domains. For example, prior research (Harm & Seidenberg 1999) has implemented a model for the pronunciation of words. Proper pronunciation was achieved from the networks capacity to extract the regularities present in the mapping between spelling and sound. Traditional approaches suggest a dual-route model with regular pronunciation rules and a separate system for the exceptions. However, these exception words display partial regularities and the quasi-regularity of English pronunciation taken as a whole, suggests that they are well suited to connectionist methods (Plaut, McClelland, Seidenberg, & Patterson, 1996).

Connectionist networks are well suited to quasi-regular domains because they learn in ways that are intrinsically graded as of a result of their inherent sensitivity to the statistical structures implicit in the input. Four connectionist principles bear particular significance for understanding the nature of this sensitivity (modified from Plaut & Gonnerman, 2000):

1.) Distributed Representations: All representations are encoded by patterns of activity on the same set of nodes such that similar representations are assigned similar patterns.

The notion of distributed representations is important because it provides a natural means to model graded representations. Specifically, it provides a concrete way in which to understand what it means for semantics and phonology to come in degrees.

2.) *Systematicity: Concerns the degree of regularity between the similarity structure of two domains. The extent to which similar inputs produce similar outputs.*

The principle of systematicity highlights how an emergent graded domain could be understood as the "convergence of code" (correlations that exist between input (form) and output (meaning)). It is because these correlations can come in degrees that networks are able to model the quasi-regularity that may exist between input and output, with fully regular relationships constituting a limit case of that quasi-regularity.

3.) Componentiality: The degree to which parts of the input can be mapped independently from the rest of the input. This principle provides a type of *combinatorial generalization that allows novel combinations of familiar parts.*

The principle of systematicity provides a means to understand how a system could capture degrees of regularity (i.e. quasi-regularity). The extent to which the componentiality principle is inherent to the connectionist architecture is debatable and design decisions have to be made about how to capture that combinatorial power (Harm & Seidenberg, 1999; Plaut et al., 1996; Li & MacWhinney, 2002).

4.) *One System: All input representations are processed by the same mechanisms such that both systematic (regular) and unsystematic (exceptions) patterns coexist and mutually constrain each other.*

To the extent that connectionist models succeed in modeling various linguistic phenomena, the principle of one-system means that the previously assumed "dual-routes" are in fact different aspects of a single system that mutually constrain processing.

Decomposition Models of Morphology

In derivational morphology, Aronoff (1976) provided an extensive analysis of many English words that partially deviate from the definition of a morpheme because they possess many but not all of the relevant properties. Consider that *grocer* seems similar to *baker* and *talker* and shares an analogy with *baker-bakery* (*grocer-grocery*) and initially seems to be complex, but *groc* has no independent meaning. Treating it as morphologically simple on definitional grounds (i.e. minimal meaningful unit) does little to resolve the issue since doing so implies ignoring its relationship to words like baker and writer. Gonnerman et al. (in-press) point to other examples where strict adherence to definition implies that blackberry and blueberry are morphologically complex, where as cranberry and strawberry are not[13], even though the latter two also refer to different berries and appear superficially to follow the modified-head structure of the first two. These examples are indicative of the inadequacy of the standard definition of a morpheme as the "minimal unit of meaning".

Given a more refined analysis of a broader range of English words, Gonnerman et. al. point out four central properties of morphological structure:

> 1) systematic: there are regularities that hold across related words such as the agentive *-er* cases discussed above; 2) productivity: knowledge of the structure of words is represented in a way that supports generalization, the comprehension and production of novel forms such as geneticize; 3) constraints: some structures are clearly disallowed; thus frienderly could not be a word in English; and 4) quasi-regularity (Seidenberg & Gonnerman, 2000; Seidenberg & McClelland, 1989): there are regularities in how words are structured but many words deviate from these central tendencies in differing degrees.

Relevant to this last point, Bybee (1985) looked extensively at the nature of the regularities between meaning and form and discovered the graded nature of morphological structure in several languages. The consequence of this is that if morphological structure is inherently graded then the clear cases of complex and

[13] In the former case, "cran" is not an independently meaningful unit and in the latter "straw" does not pertain any way to the meaning of strawberry.

simple words actually form two ends of a spectrum with the deviant words falling at various places in between. Further, any categorical distinction becomes arbitrary and potentially misleading. The use of rules in any traditional decomposition model will fail to avoid the commitment to a categorical division in addition to being unable to naturally capture the graded ontology of morphological structure.

If this is correct, then decomposition models can never adequately provide a proper understanding of morphology because of its graded ontology. Further, empirical attempts to isolate effects attributable to morphological structure have failed to eliminate both semantic and phonological confounds within the same experiment, leaving open the possibility of an interaction between the two that gives rise to the morphological effects. The idea of morphology as surfacing from the convergence of meaning and form would naturally accommodate the graded nature and subsequent quasi-regular/probabilistic information present in language.

Attempts to Isolate Morphology

Researchers have attempted to empirically explicate the role that semantic and formal factors play with respect to morphology. The standard logic has been to provide evidence of morphology as a distinctly represented linguistic structure by demonstrating effects of processing that are above and beyond those attributable to semantics, phonology and orthography. However, isolating morphology has the inherent difficulty that its structure is highly correlated with formal and semantic properties of words. Traditional theories have approached the problem with an isolate and eliminate strategy. That is, they attempt to solve the problem by controlling for only one factor at a time. The ultimate problem with such an approach is that it is only valid if the additional assumption, that the effects of semantic and formal factors are independent, is true. If however these factors interact in non-additive ways to produce their effects, then the above research strategy is false, in principle (Gonnerman, et al., in-press)[14].

One of the quintessential examples of the above research strategy was Murrell and Morton's (1974) comparison of priming effects for word pairs with the same root morpheme (*car-cars*) and those with comparable visual similarity but no morphemic relation (*car-card*). The results of that study showed significant facilitation for recognition of the morphemically related target and only slight non-significant facilitation for the formally related target. On the basis of this result Murrell and Morton concluded that these priming effects were the result of the morphological structure present for *car-cars*. However, the first word pair is also semantically related while the second pair is not, leaving open an interpretation that attributes the priming effects to the words pairs' semantic structure.

With their focus on meaning, Kemply and Morton (1982) controlled for semantics while confounding phonology. In their study, regularly inflected words (*reflected – reflecting*) produced significant priming whereas irregularly inflected forms (*held – holding*) did not. They concluded that the facilitation was the result of morphemic structure and not semantic properties. The problem with such a conclusion is that there is a phonological confound; specifically, the irregular forms overlap significantly less than the regular forms. To address this concern, Kemply

[14] The examples to come and the reasoning behind the underlying structure of the above criticism are taken from Gonnerman et al., in press.

and Morton reasoned that if the effects of priming were purely the result of phonology then there should be equal facilitation for the inflected forms (*reflected – reflecting*) as for phonologically similar words (*part – party*); however, the facilitation was not equal. Thus, having controlled for phonology by introducing a semantic confound they went full circle and concluded that facilitation for morphologically related pairs was not the result of either semantics or phonology.

Gonnerman, et al. (in-press) point out that the principled problem with all decomposition theories is how to determine what constitutes a morpheme in addition to what and how the rules operate on these primitive meaningful units. No independent and principled demarcation criterion has successfully established what constitutes a morpheme because there are many words that deviate from this ideal.

Empirical Support for Convergence Theory

Gonnerman et al. (in-press) have investigated the idea that morphological effects are emergent from the degree of phonological and semantic overlap with the subsequent result that these effects are graded rather than categorical. Two of Gonnerman et al.'s experiments are of particular interest. One in which Gonnerman et al. hypothesized that if phonological properties were held constant, then the magnitude of the priming effects would be modulated by the degree of semantic relatedness. This was demonstrated using a cross-modal lexical decision task with three levels of semantic relatedness (high, medium and low) between derived words and their stems (e.g. the word pair *boldly-bold* was rated as highly related whereas *hardly-hard* was judged[15] to be unrelated). Consistent with this hypothesis, *boldly – bold* primed more than *lately – late* primed more than *hardly – hard*. Further, the graded priming effects were highly correlated with semantic similarity ratings between derived-stem pairs (i.e. *boldly-bold* was more semantically related than *lately-late*, etc.). Finally, their finding that there was no priming for words that are only related in form (*hardly – hard*) serves to replicate findings by Marslen-Wilson et al. (1994). While Marslen-Wilson et al. used their findings to conclude that formal overlap does not contribute to priming effects, Gonnerman et al.'s analyses of graded interactions revealed that the effects of formal overlap are modulated by the degree of semantic similarity. A second experiment by Gonnerman et al. demonstrated the converse; that is, when the range of semantic similarity was restricted to stimuli that were all highly semantically related, it was the degree of phonological overlap that modulated the graded priming effects.

In sum Gonnerman et al.'s experiments are able to: 1.) account for effects that have previously been attributed to morphological structures; 2) demonstrate that variations in the degree of semantic and phonological overlap result in graded priming effects. In other words, these findings demonstrate that morphological interpretations are not necessary to account for the empirical findings.

Adult Morphology Processing: Affix Ordering, Parsability and Phonotactics

Priming research that looks at morphology in adult processing has investigated the role of differences in affixes (prefix or suffix), the distinction

[15] Semantic relatedness judgments were based on a similarity pretest from which the stimuli for this experiment were selected.

between inflectional and derivational morphemes, type, token and base-to-complex-word relative frequency, the relevance of semantic and phonological transparency, phonotactics across morpheme boundaries, lexical category, predicate-argument structure, compounding, and finally, specific properties of the affixes themselves: length, confusability, homonymy and productivity (Baayen, 1994; Baayen & Lieber, 1991; Baayen & Renouf, 1996; Bertram, Laine & Karvinen, 1999; Bertram, Schreuder & Baayen, 2000; Feldman & Larabee, 2001; Felman & Soltano, 1999; Feldman, Rueckl, DiLiberto, Pastizzo, & Vellutino, 2002; Hay, 2001; Hay, 2002; Libben, 1998; Marslen-Wison, et. al., 1994).

However, not only are there a large number of factors involved in the processing of complex words, but as Hay (2002) has argued, it may be unwise to detach "affix-specific" properties from the "complex-word-specific" properties in which they occur. Hay provided evidence in support of a parsability-based account of affix ordering; that is, an account in which stacking restrictions on affix ordering (e.g. adding *–ist* to *–tion* to make ***abortionist*** but not *–ic* to *–ness* to make *happinessic*) is reduced, largely, to parsability: easily parsed affixes should not occur inside those that resist parsing. Understanding affix ordering in terms of parsability also accounts for the "dual" behavior of certain affixes: an affix may resist attaching to certain complex words but display no resistance with other, comparable, complex words. Hay suggests that this "dual" behavior is modulated by the decomposability of the complex word being appended. Hay elaborates the nature of the symbiotic relationship between affixes and their bases in her analysis of two factors that contribute to decomposition: phonotactics across morpheme boundaries, and the relative frequency between a derived form and its base.

Phonotactics concerns the patterns of phoneme sequences that are found in a language such that some sequences are more likely than others[16]. Hay argues that English speakers use phonotactics to segment words into component morphemes such that if the sequence of phonemes across morpheme boundaries is highly unlikely, then people tend to posit a boundary and favor decomposition. To use her example, *pipeful* has a low-probability phonotactic transition /pf/ and so the suffix is particularly salient and the word is judged to be more decomposable than say bowlful. In sum, complex forms with low-probability phonotactics across morpheme boundaries are more likely to be judged as complex and display properties of decomposition than those that have fully regular phonotactics.

A second factor that may affect the relative ease with which complex words can be decomposed is relative frequency. Hay (2001) has taken issue with the traditional assumption that high-frequency complex forms tend to display characteristics of non-compositionality (lexicalization) and argued instead that it is relative frequency (ratio between derived form, swiftly, and its base, swift) rather than absolute frequency that affects the decomposition of complex words. If this is true, then it has direct implications for the, often implicit, assumption that derived words with the same affix form a relatively homogenous set. Given that both phonotactics and relative frequency are properties that emerge in the context of both

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[16] Sensitivity to the distributional phonotactics of a language has been demonstrated as early as 8-months (Saffran, Aslin, & Newport, 1996b) and is argued to play a role in the segmentation of speech (Saffran, Newport & Aslin, 1996a).

an affix and its base, it becomes clear why the properties of affixes cannot be sensibly detached from the word's specific properties in which they appear.

Productivity

Productivity is one of the central principles suggested to be operating in acquisition and its investigation in adult processing is crucial towards elaborating on a comprehensive account of morphology. Baayen and his colleagues have examined whether the productivity of a morpheme plays a crucial role in whether or not it will be used in the construction of new words. Baayen and Renouf (1996) conducted a corpus study looking at productive and nonproductive suffixes in English. They found that significantly more new words made use of the more productive affixes -*ness*, -*ly* and *un*– versus the less productive affixes -*ity* and *in*–. In an earlier study, Baayen et al. (1991) attributed the differences in productivity values to the categorical nature (i.e. verb, noun, adjective) of the base words selected. For example, -*able*, -*ee* and –*er* are all subject to syntactic restrictions involving predicate argument structure on the verb to which they attach, rather than to phonological or morphological restrictions.

However things are more complicated. Bauer (2001) points out there is disagreement about what is productive (affixes, morphological processes, rules, language system as a whole, etc.) as well as what productivity is (frequency of output words, frequency of input category, proportion of the words used to the number of words potentially created, possibility of forming new words, probability of new forms occurring, number of new forms occurring in a specific period of time). In addition, research looking at productivity in adult processing almost universally assumes a dual-route decomposition framework in which attempts are made to determine what gets stored whole versus what gets decomposed.

Bauer suggests that productivity applies to certain morphological processes and that productivity is the potential for repetitive non-creative[17] morphological coining. As Clark (1993) notes, if productivity is to be defined in terms of the potential to coin new words, then the only evidence available for its measure is that of past formations. However, equating productivity of a process with the number of words that have been produced by that process will not work for two complementary reasons. First, some word formation processes seem productive but are infrequent (prefix *a-* in *ablaze*, *aflutter*). In other cases, the input class is just small (*step-* in *step-father*). Second, some word formation processes do not seem productive but are frequent (suffix *–ment* has over 400 forms).

Any attempt to resolve this problem in terms of proportions of actual to potential forms encounters two other complementary problems (Bauer, 2001): the form of a derivative often fails to reflect those processes by which it was formed (e.g. *length* from *long*) and many words that appear to be the product of a productive process are actually borrowed from another language (*acceptable*, *changeable*, *desirable* and *measurable* are all borrowed from French). Put simply, legitimately derived forms may be left out and borrowed forms may be included.

[17] The inclusion of repetitive and non-creative is intended to eliminate situations in which new words are coined but the process is not productive (i.e. simplexes – blends, acronyms, shortening, back-formations, half compounds) because they have no morphological structure at all and often occur in isolation.

Baayen (1994) discusses productivity in terms of the probability of using a given morpheme in the construction of new complex words. That is, in novel complex word construction situations, there are multiple possibilities available only one of which will be used. For example, a person who makes faxes could be denoted as a *faxer*, a *faxist*, a *faxian* or a *faxman*. The more productive the morpheme the greater the probability that it will be used. In an attempt to quantify a measure of productivity, he considers the number of words formed by a process that occurs in a given corpus exactly once (the hapax legomena) relative to the total token frequency of words derived from that process in the corpus. Formally; $\wp = n_1/N$. n_1 is the hapax legomena and N is the token frequency. The reason hapaxes provide a guide to the expected number of new coinages is because for productive formations, the number of possible formations is very large and "the larger the number of potential types, the less likely it is that they will all occur in a given corpus ... and some of the many possible types are likely too have been sampled only once" (Bauer, 2001, p. 150). As for the token frequency in the denominator, given the assumption that lexicalized types have a high token frequency, high token frequency should be an indication of weaker productivity.

While there are various objections to the adequacy of Baayen's proposal, the most general one seems to be from Van Marle (1992 as cited in Bauer, 2001). His point is that it is unclear that there is a direct relationship between the chance of a formation process being used and the frequency with which words already coined by that process are used. "Once a word is coined, the frequency of use of that word, it seems to me, is more or less irrelevant to the degree of productivity of that rule" (as cited in Bauer, 2001, p. 153).

It was previously expressed that the principle of productivity could be understood as a preference for those devices used most often in language, however, this definition is incomplete. The devices used most often in a language indicate what has become conventional and (at best) what was productive in the past. An adequate notion of productivity must be construed in terms of current preferences for the coining of new words (Clark, 1993).

For Clark, productivity is constituted in the collective preferences of at least three factors: 1) structural conditions on affixes – some options are not structurally possible; 2) construction types that are transparent and favor simplicity; and 3) the usefulness of certain word-formation options. Clark states that "these collective preferences are captured by the notion of productivity:

> Productivity: In forming new words, speakers rely on the most productive option with the appropriate meaning" (p.136).

Clark suggests further, that because speakers preferences have a multiplicity of causes, the best measure of productivity is to look at the actual word-types favored in lexical innovations – that is, that coinage preferences have to be determined empirically.

While Clark seems correct to point out the necessary future orientation of the notion of productivity and some of the multiple factors involved with it, it is unclear what sense of usefulness she has intended for factor (3) above. Further, it is not evident why the multiplicity of causes precludes the possibility of a non-empirical measure of productivity. Given their natural affinity for multiple interacting causes, perhaps a dynamical systems or connectionist perspective would serve to better illuminate Clark's position on the issue.

Productivity has essentially been defined as the probability of a morphological process to coin new words. Numerous other factors (type frequency, phonological and semantic transparency, naturalness, structurally possible options, usefulness, etc.) play a role in that potential. Whether productivity is considered to be something above and beyond some of the various factors related to it (Bauer, 2001), or whether it is simply the collection of these factors (Clark, 1993) does not seem to have a definitive answer. What does seem clear is that productivity cannot be equated with any of these factors, the most tempting of which are type frequency[18] and semantic transparency[19]. It also seems clear that productivity cannot be understood as applying to processes absolutely[20]; though this latter position does not imply some sort of 'radical relativism'. Our intuitions demand that a productive process be invariant across some contexts, but which ones remain to be determined.

The Current Project

While much of the long-standing morphology debate has centered on inflection, adult processing studies have shifted that focus to derivation[21]. Further, hypotheses concerning the mechanisms that may underlie the development of

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[18] As discussed above, current type frequency is the result of past productivity.
[19] We have both transparent but unproductive affixes (*-ment*) and productive but not transparent affixes (add *-ity* to adjectives ending in *–able* producing nouns ending in *–ability*).
[20] At a minimum it is not invariant across time.
[21] It has been suggested by some (Bauer, 2001; Bertram, Schreuder & Baayen, 2000) that the distinction between inflectional and derivational morphology is itself a cline.

inflectional morphology in children have helped to constrain (and inform) hypotheses about the processes involving complex words for skilled language use in adults. The particular derivational acquisition findings by Clark (1993) have served as the primary motivation for the current research. The purpose of the two current experiments is to look at certain productive and nonproductive (less productive) affixes and how they affect the speed of processing for complex English words. Previous work by Bertram and colleagues (1999, 2000) suggests that morphemes with different levels of productivity in both Dutch and Finnish produce differential priming effects.

Many psycholinguistic studies, including the present one, involve priming. Priming can be broadly defined as the facilitation of some current behavior (usually reaction time) given relevant prior experience. With respect to the lexical decision paradigm, participants are faster (facilitation) to respond that a string of letters is a word (current behavior) if that word was preceded by a related word (relevant prior experience) than if proceeded by an unrelated control (the baseline). Importantly, it is the assumed[22] nature of the relationship between the prior experience and current task that determines the "type" of priming that is taking place. For example, if the two words in the experimental condition are semantically related and there is facilitation, then there is semantic priming. If the two words in the experimental condition are

[22] Facilitation simply means that something about the prior experience was related to the current behavior such that it reduced reaction time; but what that something is, must be decided by the researcher and is implicit in their experimental design. This is why Plaut et al. (2000) do not reject that there are "morphological" effects (i.e. that there is facilitation) but rather they reject that the nature of that facilitation is derivative from morphological structure.

phonologically similar, then the facilitation would be termed phonological priming. Given that a multitude of factors can produce priming, it is very important that the selected stimuli in the control condition only differ on the factor under consideration.

The present experiments explore whether primes with more productive suffixes will tend to facilitate processing of target stems more than those with less productive suffixes. Specifically, the agentive suffixes *–er*, *–ist*, *-ian* and *–man,* and the adjectival suffixes *–y, –ish* and *–ous* will be examined. The central hypothesis is that primes with more productive suffixes will tend to facilitate processing of target stems more than those with less productive suffixes. That is, the crucial comparisons are between those targets that are preceded by a highly productive prime (*-er* or *-y*) and those that are preceded by less productive primes (*-ist* and *–ian* or *–ish* and *-ous*).

Experiment 1: Priming for Agentive Suffixes, *-man*, *-er*, *-ian* and *–ist.*

The first experiment was designed to examine the differential priming effects of more and less productive English suffixes. Specifically, to look at the degree to which words ending in the agentive suffixes *–man*, *-er*, *-ian*, and *–ist* would primed their base. For example, it is anticipated that participants primed with *baker* will respond faster to *bake* than those primed with *artist* responding to *art*, because *–er* is more productive than *–ist*.

Method

Participants

Eight-one Lehigh University undergraduates participated in a semantic similarity pretest survey for course credit. Another 64 Lehigh University undergraduates participated in the current experiment as a part of their course credit for Introduction to Psychology.

Materials

The prime-target word pairs used in each experiment (*baker-bake* vs *artist-art* or *dirty-dirt* vs *gaseous-gas*) were balanced for semantic and phonological transparency as well as token frequency and word length. Equating prime-target pairs on the dimension of phonological transparency is necessarily imperfect – words ending in *-ist* (*scientist*) tend to distort their stems (*science*) more than words ending in *-er* (*runner – run*) – though care was taken to minimize this intrinsic shortcoming. Semantic transparency was controlled for using semantic similarity judgments for contrasting word pairs. That is, comparing the semantic similarity of a complex word ending in *-er* with its stems (*baker-bake*) was equated with similarity ratings for a complex word ending in *-ist* and its stem (*artist-art*). These similarity ratings were derived from a pretest survey taken by Lehigh undergraduates. There were five different surveys with a random selection of prime-target word pairs; in addition, 30 pairs of unrelated words were added. Participants were asked to rate the semantic similarity of each word pair (*baker-bake, artist-art, dentist dent*) using a scale from 1 (unrelated) to 9 (highly related) and were encouraged by the experimenter to use the entire scale.

Mean similarity ratings were calculated for each pair of words. 25 words ending in each suffix (*-er, -ist, -ian,* and *–man*) were selected from the larger corpus as the prime-target pairs to be used in the first experiment. All word pairs had a mean semantic similarity rating of at least six. In sum, the prime-target word pairs for the four suffixes all controlled for semantic and phonological similarity as well as token frequency and word length. A control prime was selected to match each of the 100 (25 words x 4 conditions) test prime-target pairs in token frequency, number of syllables, length and part of speech. Test and control primes were not phonologically or semantically related. To avoid participants developing experiment-specific response strategies, 200 non-word fillers were included, 50 of which were phonologically related (*slither-slith*), and 150 others that were not (*basil-grook*). Finally, 100 real word, unrelated fillers were also used (*football-mouse*). The items were then divided into two lists using two separate, pseudo-random, orders: if the first list contained the test-target pair (*scientist-science*); then second list contained the control-target pair (*pumpkin-science*) and vice versa. Participants were tested on the stimuli from only one of the lists. Finally, the same native female English speaker was used to digitally record all of the test and control primes.

Procedure

Participants were tested individually. They were seated in front of a computer roughly two feet from the monitor and listened to the primes (related and unrelated) over headphones. The participants were required to respond yes or no on a button box in accordance with whether they judged a target to be a word or a non-word. The experimenter encouraged participants to respond as quickly as they could without making too many errors and to slow down if they were. Psyscope software (Cohen, MacWhinney, Flatt, & Provost, 1993) was used to present stimuli and record responses.

Each trial started with a fixation point displayed at the center of the monitor for one second, followed by the presentation of the auditory prime over the headphones. At the offset of the prime the visual target was displayed on the monitor for 200 ms. By pushing either yes or no on the button box participants ended the trial and there was a 500 ms delay until the next trial began. Targets were displayed in lower case letters. In an effort to maximize the amount of attention participants were giving to the auditory primes, the instruction "Please repeat the word you just heard" was displayed on the screen on 15% of the trials. Participants were led to believe that their responses were going to be digitally recorded, though they were not. After repeating the word participants were instructed to press either of the response buttons to continue with experiment.

The experiment began with 20 practice items, followed by four warm-up items before the 400 test items were presented. Thirty-two participants were tested on each of the lists. The experiment took approximately 25 minutes to complete: including practice, warm-up, test trials and debriefing.

Results and Discussion

Prior to any analysis, data from 12 participants were excluded because they did not qualify as native English speakers[23]. Data from three participants were excluded due to high error rates (over 10%). After removing these participants, data from eight items were excluded due to low accuracy rates (under 75%); only one of these was from a condition of interest (*obstetrics* from condition 3). Finally, the second

[23] Participants were considered non-native English speaker if any caregiver living in the home did not have English as their native language. Additionally, if the participant learned another language before age three they were also excluded.

occurrence of two other items were removed (*guard* and *music*) because they were unintentionally duplicated as primes within the same list. Both of these items were from a condition of interest (condition 1 and 3 respectively).

Trials on which participants made an error (2.9%) were excluded from the latency analysis as were any outliers – responses greater than 2000 ms or less than 200 ms (2.04%). The distribution of errors across conditions is displayed in Table 2. Conditions two (*-er*) and four (*-ist*) are roughly equal and display the most errors. Conditions one (*-man*) and three (*-ian*) are roughly equal[24] though 2.5 – 3 times less frequent. The remaining decision latencies were entered into a repeated measures analysis of variance with the factors Prime Type (related or unrelated) and Condition (the four types of morphologically relevant prime-target relations: *-man* words, *-er* words, *-ian* words and *-ist* words). All means presented are based on a participant analysis[25]. A descriptive summary of the data is presented in Table 3.

A repeated measures ANOVA was conducted to assess whether there were differences in the amount of priming across suffix conditions. Sphericity was violated for the Prime by Condition interaction effect, $\chi^2 = 15.00$, $p < .05$, though Greenhouse-Geisser correction did not alter the value of the F-statistic or decision for any of the effects. There was a significant main effect of Prime, $F(1, 45) = 33.60$, $p <$

[24] Condition three has one word (obstetrics) that accounts for almost half of the total errors for that condition. The suggested "rough equivalence", presupposes that this outlier has been removed.

[25] Raaijmakers, Schrijnemakers, & Gremmen (1999) point out that there is no need to run separate participant and item analysis if the experimenter controlled for item variability through matching or counterbalancing. In the current experiment all items were matched for semantic and phonological transparency as well as token frequency and word length.

.05, (M_{prime}= 697, $M_{control}$= 752) indicating that it was generally less difficult to respond correctly to the targets when they were preceded by related primes compared to unrelated controls. There was a significant main effect of Condition, $F(3, 135) = 13.83$, $p < .05$ (M_{-man}= 677, M_{-er}= 742, M_{-ian}=735, M_{-ist}= 744); however, this result is not of interest to the current project because it is looking at differences in priming not in absolute values. There was also a significant Prime by Condition interaction, $F(3, 135) = 8.09$, $p < .05$, indicating that the amount of priming differed across the four suffix conditions.

The overall pattern of results for this experiment indicates that priming effects between pairs of related words differ depending on the degree of productivity such that priming mostly increases with more productive morphemes (i.e. *baker – bake* primed more than *comedian – comedy*). This pattern is consistent with the general hypothesis that there would be differential priming depending on the degree of productivity of the suffix. However, the pattern is not consistent with the specific prediction that priming effects would universally increase with an increase in productivity. Polynomial contrasts indicated, contrary to our specific predictions, that there was not a significant linear trend, $F(1, 46) = 2.38$, p = ns.

Finally, four pair-wise t-tests were conducted to look at the amount of priming for each condition. Using Bonferoni correction alpha was reduced to .013. The results indicated that there was significant priming for *–man*, $t_{(46)}$= 4.54, $p < .013$ (M_{prime}= 656, $M_{control}$= 696), *-er*, $t_{(46)}$= 2.88, $p < .013$ (M_{prime}= 698, $M_{control}$= 789), and *–ist*, $t_{(46)}$= 5.98, $p < .013$ (M_{prime}= 692, $M_{control}$= 798), but not *–ian*, $t_{(46)}$= .15, p = ns

(M_{prime}= 734, $M_{control}$= 736) indicating that the differential priming across conditions is above and beyond the tendency of derived words to prime their base.

Experiment 2: Priming for Adjectival Suffixes, *-y, -ish* and *-ous*

The second experiment was designed to examine the differential priming effects of a different class of more and less productive English suffixes. Specifically, to look at the degree to which words ending in the adjectival suffixes *–y, -ish* and *-ous* would prime their base. For example, it was anticipated that participants primed with *chilly* would respond faster to *chill* than those primed with *suspicious* responding to *suspicion*, because *–y* is more productive than *–ous as well as –ish.*

Method

Participants

The same 81 Lehigh University undergraduates from experiment one participated in a semantic similarity pretest survey for course credit. Another 44 Lehigh University undergraduates participated in the current experiment as a part of their course credit for Introduction to Psychology.

Materials and Procedure

The second experiment involved an identical materials selection and procedure. It differed only in that the two lists used contained different suffixes (*-y*, *-ish*, and *-ous*) and there were a total of 360 word and non-word stimuli. The difference in stimuli was because only three suffixes were used, with 30 tokens each (30x3 = 90) 90 controls; and 180 non-words = 360). Twenty-two participants were tested on each of the lists. Finally, the experiment took approximately 25 minutes to complete: including practice, warm-up, test trials and debriefing.

Results and Discussion

Prior to any analysis, data from four participants were excluded because they did not qualify as native English speakers. Data from three participants were excluded due to high error rates (over 15%). After removing these participants, data from 16 items were excluded due to low accuracy rates (under 75%) none of which were from a condition of interest (conditions 1-3).

Trials on which participants made an error (2.75%) were excluded from the latency analysis, as were outliers – responses greater than 2000 ms or less than 200 ms (2.24%). The distribution of errors across conditions is displayed in Table 4. Conditions two (*-ish*) and three (*-ous*) are roughly equal[26] and display the most errors. Condition one (*-y*) has a little under twice as many errors as do the other two conditions. The remaining decision latencies were entered into a repeated measures analysis of variance with the factors Prime Type (related or unrelated) and Condition (the three types of morphologically relevant prime-target relations: *-y* words, *-ish* words, and *–ous* words). All means presented are based on a participant analysis. A descriptive summary of the data is presented in Table 5.

A repeated measures ANOVA was conducted to assess whether there were differences in the amount of priming across suffix conditions. Sphericity was not violated for any of the effects. There was a significant main effect of Prime, $F(1, 35)$

[26] Condition two has one word (ghoul) that accounts for almost ¼ of the total errors for that condition and is almost 4 SD above the mean. The suggested "rough equivalence" presupposes that this outlier has been removed.

$= 51.44$, $p < .05$ ($M_{prime}= 705$, $M_{control}= 772$), indicating that it was generally less difficult to respond correctly to the targets when they were preceded by related primes compared to unrelated controls. There was a significant main effect for Condition, $F(2, 70) = 12.64$, $p < .05$ ($M_{-y}= 771$, $M_{-ish}= 713$, $M_{-ous}= 732$), indicating that it was probably less difficult to respond to *–ous* words, than *–ish* words, than *–y* words; however, this result is not of interest to the current project because it is looking at difference in priming not in absolute values. There was not a significant Prime by Condition interaction, $F(2, 70) = .82$, ns, indicating that the amount of priming did not differ across the three suffix conditions.

The overall pattern of results for this experiment indicates that priming effects between pairs of related words differ depending on the degree of productivity such that priming decreases with more productive morphemes (i.e. *bouncy – bounce* primed less than *gaseous – gas*). Although the pattern of results is consistent with the general hypothesis that there would be differential priming for the different suffixes, the direction of the trend is opposite to that which was predicted (i.e. that *–y*, as the most productive suffix would prime more than *–ish* and *–ish* would prime more than *–ous*). Polynomial contrasts indicated, contrary to the specific predictions, that there was not a significant linear trend, $F(1, 35) = 1.04$, p = ns.

Finally, three pair-wise t-tests were used to look at the amount of priming for each condition. Using Bonferoni correction alpha was reduced to .017. The results indicated that there was significant priming for all three conditions. For *–y*, $t_{(35)}= 4.06$, $p < .017$ ($M_{prime}= 743$, $M_{control}= 799$), *-ish*, $t_{(35)}= 5.42$, $p < .017$($M_{prime}= 675$, $M_{control}= 750$), and *–ous*, $t_{(35)}= 5.84$, $p < .017$ ($M_{prime}= 696$, $M_{control}= 767$), indicating that the differential priming across conditions is above and beyond the tendency of derived words to prime their base.

General Discussion

Productivity seems to play a crucial role in the development of morphology in children. Clark (1993) argued that productivity is one of four central interacting principles that give rise to the subsequent trajectories found in acquisition. Further she suggests that productivity is dynamic, both for children during acquisition and for the broader speech community. In other words, what is productive for any speaker changes over time making the use of past formations an incomplete indicator of present productivity. For this reason Clark suggests that the best measure of current productivity lay in the actual word-types favored in lexical innovations. Consistent with this criterion, Baayen and Renouf (1996) looked at a number of English suffixes in a British newspaper to provide support for the notion of degree of productivity and to demonstrate that productivity seems to vary as a function of the morphological structure to which a productive affix attaches. While these researchers were not looking at the productivity of particular affixes per se, they were interested in whether productive affixes which tend to appear earlier in the child's productive vocabulary also produce an advantage in adult processing.

Affixes from both studies displayed differential priming effects depending on their degree of productivity; however, in the first study, only three of the four suffixes produced priming effects corresponding to the degree of productivity, and in the second study, there was no evidence of differential priming effects.

Experiment 1

Experiment 1 looked at *–man*, *-er*, *-ian* and *–ist*. Of these *–er* is the most productive followed by *–man*, and then *–ist* and *–ian*. The pattern of results was consistent with the prediction for *–er* (91 ms), *-man* (40 ms) and *–ian* (2 ms); however, *-ist* displayed the most priming of any of them (106 ms, see Table 3). This is worth noting as *–ist* is not more productive than *–er* or *–man*.

To answer the question of why the *–ist* suffix showed so much priming, it is useful to consider Hay's (2001) discussion of decomposability. Hay argues that the dominant assumption that high-frequency complex forms tend to display characteristics of non-compositionality seems to be false; instead, decomposability is determined, in part, by relative frequency and phonotactics. Relative frequency, as previously discussed, is the ratio between the (token) frequency of the derived form and the (token) frequency of the base form. Two of Hay's experiments, one involving complexity judgments and the other semantic drift, provided evidence for the conclusion that high frequency forms are likely to be highly decomposable if they are less frequent than their base (*infirm* < *firm*), but highly non-compositional if they are more frequent than there base (*insane* > *sane*). Phonotactic transitions suggests that complex forms with low-probability phonotactics (phonemes sequences) across morpheme boundaries are more likely to be judged as complex and display properties of decomposition than those that have fully regular phonotactics across morpheme boundaries.

Hay's analysis of decomposability may be related to Bauer's (2001) discussion of lexicalization. One of the reasons for not equating productivity with type frequency was that a derived form often fails to reflect those "productive" processes by which it was coined (e.g. *length* from *long*). That is, word formations have a tendency to diverge from the synchronically productive methods that formed them – lexicalization. If there is a gradual diachronic shift from coinage to lexicalized word, then presumably high token frequencies play an important role in that process. The exact dynamics for why the relative frequency and phonotactics of these high frequency forms seem to be the key remains unknown but decomposability may explain why *–ist* demonstrated "disproportional" priming. Specifically, *–ist* words (psychologist, psychiatrist) may have been less decomposable than *–man* and *–er* words (*guardsman, enchanter*) meaning that they were stored as "lexicalized items"[27] and therefore demonstrated greater gains from the priming.

One anomaly remains: why did the derived words using *–ian* not prime their bases? Numerically, items in the *–ian* condition did not prime their bases because there are nearly equal amounts (and magnitudes) of numeric inhibition and numeric facilitation even though the standard deviations for *–ian* were within the range of the other three conditions. However, the standard deviation for the control was smaller than for the prime and the magnitude of this difference and the direction (control < prime) does not follow the pattern of the remaining conditions. In short, even though the variability for the *–ian* condition was congruent with the other three, the magnitude of difference between control and prime and direction was not. What relevance this may have for the failure of derived *–ian* words to prime their bases

[27] Lexicalization is itself a gradual process and if the basic core of Convergence Theory is correct there is no sharp distinction between lexicalized and productive word storage.

remains, at best, vague; though the same pattern was observed for the *–y* condition in experiment 2 which also seems to have displayed attenuated priming effects.

Linguistically, the failure of derived *–ian* words to prime their base may be related to the fact that *–ian* words have the least amount of phonological transparency (*pediatric – pediatrician, statistics – statistician*) and this was a cross modal lexical decision task in which participants heard the prime and saw the target. Although *–ist* words also distort their stem (*physics – physicist*), the vowel change required for *–ian* words is not present. However, the lack of transparency is part of the reason why *–ian* is less productive than *–man* or *–er* in the first place so this does not account for the lack of priming altogether.

Another factor that may have contributed to the lack of priming for *–ian* words has to do with the fact that it had a low percent derived value relative to its token frequency (See Table 1). The token frequency for *–ian* words (360) was comparable to that of *–ist* (303) and *–man* (440) but the number of those that were making use of *–ian* as a suffix was only 29%. The agentive use of *–er* was also low (32%) but with more than 10 fold the number of total tokens (4224). This means that during the acquisition of *–ian,* as an agentive morpheme, children are exposed to many more instances in which *–ian* appears but is not playing its agentive role.

Experiment 2

Experiment 2 looked at *–y*, *-ish*, and *–ous*. Of these, *–y* develops first and is the most productive, *-ish* and *–ous* develop later and are less productive respectively. The pattern of results however was almost the exact opposite of what was expected.

That is, *-y* primed the least (56 ms), followed by *–ous* (71 ms) and *–ish* (75 ms, see Table 5).

Unlike the suffixes from experiment 1, there has not been developmental work that looked at the acquisition trajectory of *–y, –ish* and *–ous.* The literature has indicated that *–ish* is more productive than *–ous* (Baayen & Lieber, 1991) and *–y* is one of the earliest adjectival developments, but there has been no explicit link between the three. As discussed above, issues raised in the earlier discussion of Experiment 1 are equally relevant for Experiment 2.

Failing to take into account relative frequency and phonotactics may have contributed to the awkward results in Experiment 2. In addition, the reversal of *–ish* and *–ous* may have been due, in part, to the greater phonological transparency of *–ish* words (*brownish, boyish*) over *–ous* words (*fictitious, monstrous*); however, this does not explain why *–y* primed less than either of them. The difference in the standard deviation for the control items and the primed items was much smaller in magnitude for *–y* and in the opposite direction (control < prime) from *–ish* and *–ous* (See Table 5). Interestingly, the atypical direction of the standard deviation for *–y* was consistent with the atypical direction of the standard deviation for the *–ian* condition from Experiment 1. The magnitude of the difference from the other conditions was much smaller than that of *–ian* but then the amount of overall priming was also greater.

Conclusion

Convergence Theory (CT) suggests that morphological effects are an emergent product of the convergence of orthographic, phonological, and semantic codes. At its core, CT attempts to capture the quasi-regularities ubiquitous in “morphological” phenomena. To test some of the empirical consequences of the CT framework, recent research with adults has demonstrated that the magnitude of priming for pairs such as, teacher-teach, is moderated by the degree of semantic and phonological overlap between the prime and the target. In addition, developmental research and adult processing studies have suggested that semantic and phonological factors are supplemented by the productivity of a “morphological” process. The current project attempted to look at how the differential productivity of a given suffix would produce graded priming effects. The results certainly showed different amounts of priming for word types that were suppose to differ only with respect to their degree of productivity. However, at least one important factor (decomposability in terms of relative frequency and phonotactics) was not controlled for and exactly how phonological transparency interacts with other factors is not clear. Future work should attempt to incorporate those factors that may have adversely affected the current project and explicit implementation in a connectionist network would help provide greater clarity as to the dynamics involved for the multiple interacting factors.

Table 1

Token Frequencies of Four Suffixes with the Percentage of Derived Tokens for Each

Affix	Token Frequency	Percent Derived	
-er	4224	54	Agent = 32 Instrument = 12 Comparative = 10
-man	440	73	
-ian	360	29	
-ist	303	71	

Table 2

Total and Mean Error Rate Across Conditions (25 words per condition - Experiment 1)

Condition	Example	Total Number of Errors Combined Across Subjects	(mean % of error per condition)
1. *–man*	mailman-mail	18	(1.41)
2. *–er*	baker-bake	50	(3.92)
3. *–ian*	magician-magic	42	(3.29)
4. *–ist*	pianist-piano	58	(4.55)

Table 3

Mean Lexical Decision Latencies as a Function of Productivity[28] (Experiment 1)

		Control	Test	
		Mean	Mean	Priming
Condition	Example	(SD)	(SD)	effect
1. *–man*	mailman-mail	696	656	40*
		(142)	(134)	
2. *–er*	baker-bake	789	698	91*
		(174)	(161)	
3. *–ian*	magician-magic	736	734	2
		(149)	(176)	
4. *–ist*	pianist-piano	798	692	106*
		(154)	(157)	

Note: * indicates a significant priming effect ($p < .05$)

[28] These are not order according to decreasing productivity, instead –er is the most productive followed by –man and then –ist and –ian.

Table 4

Total and Mean Error Rate Across Conditions (30 words per condition – Experiment 2)

Condition	Example	Total Number of Errors Combined Across Subjects	(mean % of error per condition)
1. *–y*	chilly-chill	76	(6.72)
2. *–ish*	brownish-brown	54	(4.62)
3. *–ous*	suspicious-suspicion	43	(3.60)

Table 5

Mean Lexical Decision Latencies as a Function of Productivity[29] (Experiment 2)

		Control	Test	
		Mean	Mean	Priming
Condition	Example	(SD)	(SD)	effect
1. –*y*	chilly-chill	799	743	56*
		(165)	(171)	
2. –*ish*	brownish-brown	750	675	75*
		(147)	(130)	
3. –*ous*	suspicious-suspicion	767	696	71*
		(158)	(131)	

Note: * indicates a significant priming effect ($p < .05$)

[29] These affixes are ordered in terms of decreasing productivity. That is, -y is most productive, followed by –ish and then –ous.

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EDUCATION

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RESEARCH INTERESTS

- Most broadly I am interested in the possibility of intelligent systems that are compatible with naturalism. Currently this interest is focused on understanding what the ontogenesis of representation could possibly look like given this naturalist assumption. My current research interests include: 1.) Language studies, with an emphasis on connectionist modeling of morphology as an emergent property of semantics and phonetics; and 2.) Development studies, with a focus on attempting to reconcile the underlying assumptions ,and subsequent motivations associated with the current trend to attribute infants with high-level cognitive capacities on the basis of looking time procedures.

RESEARCH EXPERIENCE

August, 2004- Present	**Graduate Research Assistant** to Dr. Laura Gonnerman, Department of Psychology, Lehigh University Assisting Dr. Gonnerman with several facets of a project in which we are investigating the relationship between semantics, phonology and morphology. These include: (a) looking at the graded behavior of subject's reaction time's in response to

morphological priming phenomena; (b) attempting to model such phenomena using the computational principles of connectionist networks; (c) exploring the implications of these principle for adult processing; (d) investigating the developmental trajectory of morphology acquisition in children.

Tasks include: assisting in the design of research projects, creating representations, constructing research equipment (baby box), overseeing specific projects; collecting data, overseeing undergraduate research assistants, conducting literature searches.

September, 2003- June, 2004	**Undergraduate Research Assistant** to Dr Bryan Sokol, Department of Psychology, Simon Fraser University Assisted Dr. Sokol with his research on child development.
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CONFERENCE PRESENTATIONS

Allen, J. W. P. (2007, June). *Why only a thoroughly action based approach can fully transcend the Navtivist Empiricist epicycles and ground mind in the natural world.* Paper talk accepted for presentation at the 4th Bi-annual Interactivist Summer Institute, Paris France.

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Grant, S., Allen, J.W., & Sokol, B. (2004, June). *The relation between children's understanding of seriation and interpretation.* Poster accepted for presentation at the 34th Annual Jean Piaget Society Conference, Toronto, Canada.

REVIEWING

2007 **Conference Reviewer** for the European Cognitive Science Society.

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TEACHING EXPERIENCE

Spring, 2007; Fall, 2006 — **Teaching Assistant**, Lehigh University
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PROFESSIONAL MEMBERSHIPS

Jean Piaget Society

Interactivist Summer Institute

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