

‘Interestingful’

**How humans infer and learn
novel compositional word meaning**

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Abstract

The present study examined how humans infer and learn novel compositional word meaning that is the result of derivational affixation, and whether and how the specific strategy they adopt has an influence on this process. This is examined through two behavioural experiments in which 40 Dutch participants were taught novel compositional words using an artificial language, after which it is tested whether they can generalise that knowledge to other novel compositional words. The target words consisted of a Dutch stem and a novel affix (e.g., *klahond* (ENG: *kladog*) meaning *puppy*). These are combined together with a sequential order rule (order-congruent) that is manipulated (order-incongruent and mismatched). The results showed that humans are able to infer and learn novel compositional word meaning by transferring previous acquired knowledge to novel contexts. Furthermore, humans are generally able to take the compositionality into account in the process of inferring and learning the meaning of novel words. Though, whether or not humans are aware of the sequential order rule of the compositional words has an influence on the exact way in which humans infer and learn novel compositional word meaning. By means of furthering our understanding on this topic, the next step is taken in bridging the gap between psycholinguistic and neurobiological accounts of language processing.

Keywords: linguistic inference, language compositionality, derivational affixation, novel compositional words, abstract rule learning, sequential order rule.

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1. Introduction

A fan of the sit-com series *Friends* might remember Ross in the scene where he accidentally got the front side of his body spray tanned several times because he counted with *Mississippi* between each count. After the instructor told him “Mississippi? I told you to count to five!” Ross astonishedly answered: “Mississippilessly?” (Crane & Kauffman, 2004).

Aside from a good laugh, the word *Mississippilessly* left more intriguing thoughts, namely about the linguistics of this particular word. When linguistically analysing Ross’ *Mississippilessly* answer, one can distract two (or even three) conceptual building blocks, namely *Mississippi* and *less(ly)*. Even though the chance of a previous encounter with this exact combination of building blocks is slim, Ross was able to generate this novel word effortlessly, and the audience and viewers of the *Friends* episode were able to infer the meaning (almost) instantly. In other words, without ever having seen this specific combination, the linguistic meaning of the novel word is inferred and thus understood effortlessly and perhaps even instinctively.

What exactly is meant by *inference*? A definition of the word would be something along the lines of steps in reasoning and the process of reaching a certain conclusion, obtaining certain information, or acquiring certain knowledge (Cambridge Dictionary, 2021). Following this, linguistic inference can be defined as the process of obtaining linguistic knowledge and using that to reach a certain conclusion (Garnham, 1989). The fact that humans have the ability to infer the meaning of novel words that consist of combinations of linguistic building blocks

with such ease is fascinating. However, many additional questions come into play when one tries to appropriately understand this process. For example, what exactly is word meaning and how is that meaning represented in our brains? What are conceptual building blocks and how can they be combined? How do we recognise and process words that consist of multiple building blocks? And most importantly, which, if any, abstract rules or strategies underlying these conceptual building blocks do we apply to understand their meanings in novel situations?

1.1 Word Meaning and the Mental Lexicon

In order to appropriately conduct research on word meaning, it is first important to comprehend what exactly is meant by meaning itself. It turns out that the meaning of meaning is enormously broad. In fact, Hagoort (2019) argued that it is not possible to define meaning itself in one single meaning. Therefore, it is important to first narrow down what exactly is meant by meaning. In her book *Language and Meaning* (2017), Birner argued that the most relevant type of meaning to a linguist would be non-natural meaning. It exists because humans have intended it to exist. For example, a green light means *go*, but only because humans had the intention to semantically correlate these two specific aspects (Birner, 2017). This example shows that meaning enables humans to artificially construct the world around us. Even though the green light example is non-linguistical meaning, language also helps us to construct meanings and subsequently to communicate. This latter argument was also put forward a decade earlier by Mahon and Caramazza (2008) because they argued that meaning serves as a door to explain the signals that one receives from one's environment. In other words, physical interactions from one's environment are inferred and turned into a word with a corresponding meaning (Mahon & Caramazza, 2008). Thus, meaning is something humans assign to certain aspects in our physical surrounding in order to understand and communicate the world around us.

After establishing what is meant by meaning, now the subject word meaning will be scrutinised. To start, it is important to note that even though a word and its meaning are both concepts, they have to be distinguished. Words are solely names for certain meanings, whereas meanings provide details about the referent or sense of a specific word (Hudson, 1995). For example, the definition of the word *rose* would be ‘a four-letter noun consisting of two vowels and two consonants’, whereas the definition of the meaning of *rose* would be something along the lines of “a flower with a sweet smell that grows on a bush with thorns on its stems” (Cambridge Dictionary, 2021). The take-home message of this is that a word’s meaning is a reflection of some sort of general agreement amongst language users (Jeffries, 1998). The present study expands on this by investigating how general these agreements actually are, especially with regard to the meaning of novel compositional words. It may be the case that individuals infer novel word meaning differently, and thus that the reflection of a word’s meaning can also differ between humans.

Words and meanings are represented and accessed in our brain in specific ways. The collection of representations of lexical units that an individual has acquired throughout their lifetime is referred to as their mental lexicon (Altmann, 2012). Simply put, this is some sort of mental dictionary that contains multiple levels of information about words, such as relevant semantical, phonological, syntactical, and pragmatic information. All this information is stored in the neural structures of our brain. However, describing the mental lexicon as a dictionary vastly negates its complexity. For instance, when looking up a word in an actual written dictionary, the way in which a word is spelled has to be taken into account before being able to actually find the right word. Moreover, the target word is surrounded by highly similarly spelled words that may or may not have completely different meanings (Altmann, 2012).

This process is far from similar to accessing and activating words in our mental lexicon. In practice, the representations of words in our mental lexicon are activated as long as they are

compatible with the input from our environment. This was described by the Cohort Model (Marslen-Wilson & Welsh, 1987), an account that proposed that (acoustic) input results in simultaneous activation of representations in the mental lexicon that fit that specific piece of acoustic input. Based on the quality of the fit, the other candidates are deleted from the list of possibilities and subsequently deactivated. As a result, the target word remains active and can be used in the specific context. This process is referred to as lexical competition (Marslen-Wilson & Welsh, 1987). The argument put forward by the Cohort Model is relevant to the present study because in the process of inferring and learning novel compositional word meaning, humans will have to activate the correct words according to the quality of fit as well. Thus, according to lexical competition, humans will deactivate irrelevant words which results in the activation of the target word.

The next step is to look at meaning. Are meanings activated in a similar fashion, in the way that all possible meanings are activated according to how well they fit the context? It turns out that this is dependent on the specific lexical unit and the context. When processing a developing sequence of letters or sounds that has more than one meaning, all appropriate meanings are activated simultaneously. For instance, two words with identical spelling (i.e., homographs) or two words with identical pronunciation (i.e., homophones) generally activate both meanings when the context is not highly restrained (i.e., when the sentence context does not clearly indicate which meaning is meant). In contrast, when the sentence is restrained (and the context thus indicates the specific meaning of the word), only the compatible meaning is activated in the mental lexicon. These findings were put forward by Tabossi (1988) in a study on ambiguous and unambiguous words in context restrained and context unrestrained sentences. In the experiment, Tabossi used homographs (e.g., the English noun *bank*) in a lexical decision task. Before the target word appeared on the screen, participants were either exposed to an unrelated word or another word that was related to either one of the meanings of

the homographs. For example, for *bank*, the word *money* (for the meaning of *financial establishment*) was shown, the word *river* (for the meaning of *riverbank*), or an unrelated word like *honey*. It turned out that, after the unconstraint sentence, participants' reaction times were the same for *money* and *river* and shorter than *honey*, which indicates that both the meanings of the word *bank* were activated. However, after reading a constraint sentence (pointing towards only the meaning of *financial establishment*), the reaction times to *money* were significantly faster than to *river*, which was read as fast as *honey*. This indicates that in this case, only the dominant meaning was activated instead of both meanings (Tabossi, 1988). The results from his study show that meaning activation within and access to the mental lexicon has no simply set course, but rather is a context-dependent and complex process that happens within the neural circuit of our brain (Altmann, 2012).

Following this, describing the mental lexicon as an intricate collection of neural circuits is the essence of the Semantic Network Theory (SNT). This theory argues that meaning activation happens in a spreading way, whereby so-called nodes and edges play a significant role. The concepts in our mental lexicon are the nodes, and the semantic connection between those nodes are what the SNT refers to as edges. Thus, the representations of meaning are connected to each other in the mental lexicon, resulting in the fact that related meanings could be activated simultaneously – hence the term *spreading activation* (Altmann, 2012).

Evidence of the hypothesised process proposed by the SNT can for example be explained by the phenomenon of semantic priming. This refers to the fact that humans process a certain word with more ease when preceded by a word that is related in meaning. This means that words somehow have a facilitating role when processing other semantically related words. The semantic priming effect can for example be found when conducting a lexical decision task in which participants are introduced to words and non-words. The results of such a task can for example show that reaction times are significantly faster to target words when they are

preceded by a semantically related word (as compared to when they are not preceded by such a word). For example, when one is exposed to the word *dog* and subsequently to the word *to bark*, the former word primed the latter to be processed faster (Traxler, 2011). Thus, the spread activation of meaning that is proposed by the SNT shows that activating meaning in our mental lexicon happens differently than when a meaning of a word is looked up in a normal dictionary. Though, in light of the present study, it is important to delve into this further, by redirecting the focus from word meaning to the meaning of word parts.

1.2 Morphemes and their Meaning Recognition

Some words consist of several conceptual building blocks, that each independently carry meaning. Throughout this thesis, such words are called compositional words. In his paper on “meaning-making mechanisms”, Hagoort (2019) argued that the meaning of such compositional words is constructed by integrating and combining conceptual building blocks. These conceptual building blocks – also called morphemes – are the smallest meaningful units of language. There are two types of morphemes, namely free and bound ones. Free morphemes are often called lexemes and are meaningful on their own. Opposed to this, bound morphemes are the ones that have to be combined with a free morpheme in order to become meaningful (Jeffries, 1998). Using the introduction’s example of Ross’ *Mississippilessly*, the free lexeme would be *Mississippi* whereas the bound morpheme(s) would be *-less* and *-ly*. An additional distinction can be made between inflectional and derivational (bound) morphemes. The former can only be a suffix (i.e., can only be added at the end of a free lexeme and not at the front), and predominantly adds grammatical information, such as number, tense, or word class. The latter can both be a prefix (i.e., can only be added in front of a free lexeme and not at the end) or a suffix, and mostly add additional information about the free lexeme it is combined with (Altmann, 2012). The focus of the present study is on the latter type specifically, as the novel

compositional words that are used to investigate the way in which humans infer and learn novel word meaning consist of a stem and a (novel) derivational affix.

There are several different ways in which free and bound morphemes and words can be combined together, which is referred to as affixation. More specifically, derivational affixation is the process of combining a stem of a word with a derivational affix, for example in the case of *dream* and *-er* resulting in *dreamer*. For derivational affixation it is always possible to clearly divide the morphemes of which the (novel) word is constructed. This results in the fact that the meaning of words that have stemmed from derivational affixation is compositional and thus predictable based on the semantics of the two morphemes that are combined together.

How does meaning recognition of morphologically complex words work in practise? For example, consider the words *apartment* and *entrapment*. The latter is connected to *entrap*, whereas the former is not related to anything like *apart*. These examples show that understanding the complete meaning of a word is a complex process because humans have to be able to understand the internal structure of a (compositional) word whilst simultaneously understanding the function of each part of that structure (Altmann, 2012). Essentially, meaning recognition for compositional words works the same as previously explained, namely through spreading activation. For example, when processing the word *entrapment*, several connected meanings will be activated, amongst which the meaning of the morpheme *-ment*. The activation of this is deactivated as soon as the remainder of the input does not match in combination with the morpheme. Following this, for a word like *apartment*, the activation of the meaning of the morpheme *-ment* will be deactivated because in that specific word, *-ment* was never defined as a derivational morpheme (Altmann, 2012). Evidence for this claim was put forward by Marslen-Wilson and colleagues (1994) in a lexical decision task for several different languages. The results from the experiment showed that activation of the stem of a certain compositional word facilitates activation of the same stem in a subsequent word, also called the priming effect.

Following this, a word like *apartment* did not cause such an effect for *apart*, showing that humans do not interpret *apartment* as a combination of *apart* and *ment*, in contrast to a word like *entrapment*, that did cause a priming effect for another word that contained the stem *entrap* (Marslen-Wilson et. al., 1990). This result indicates that words do not have one individual lexical representation, but rather that morphemes have their own representation in the mental lexicon. In meaning recognition and meaning activation, those individual representations are activated and combined together (Altmann, 2012).

Thus, turning back to the word *dreamer*, the meaning of that word is easy to predict because one knows the meaning of *dream* and the meaning of the suffix *-er*. The same goes for the example that was provided in the introduction. The meaning of Ross' invented word *Mississippilessly* is inferred quite instinctively because one knows the meaning of *Mississippi* and the meaning of the suffix *-less* (and suffix *-ly*). In light of the present study and following the aforementioned theory, humans will have a separate mental representation of the meaning of the novel derivational affix, which will be combined with the meaning of other previously acquired meanings (of stems) in order to infer the complete meaning of the novel compositional words.

1.3 Language Compositionality

Thus, when analysing word meaning, it is important to regard the way in which the word is constructed. In the case of compositional words (i.e., if the word consists of multiple conceptual building blocks, it should be considered how those different meaningful units are combined together, and how that leads to (novel) word meaning. The process of combining several pieces of information together is often referred to as language compositionality. Coined by philosopher Gottlob Frege in 1882, language compositionality refers to the fact that the meaning of a (complex) text, sentence, phrase, or word is predominantly determined by the

meanings of the constituents it consists of. As this description is quite broad, Partee (2008) attempted to elucidate on the extensiveness of the topic in a selection of papers on language compositionality. In her conclusion, she described that an attempt to demarcate language compositionality increases the possibility of constraints and conflicts when one tries to put it into practise (Partee, 2008). Following this, the present study does not try to narrow down the meaning of language compositionality but rather attempts to explain in detail the way in which it fits the design of the present study. That is, throughout this paper, the attention will be primarily aimed at language compositionality on word level.

Recently, Martin (2020) put forward a description of language compositionality that fits the focus of the present study. According to her, language compositionality describes the process as constituent parts that together construct into meanings. Additionally, these meanings are not only computed by those parts, but by the regulations (or *rules*) used to make that specific combination as well. In other words, meaning does not only originate from combining several meaningful constituents, but also from the rules that are used to combine those constituents. Those rules could be, for example, whether a certain word part should be in front or after another word part (i.e., whether it is a prefix or an affix). Martin (2020) also argued that language compositionality regards the connection between the meaning of a word (and/or its constituent parts) and the form of a word (and/or its constituent parts). Following this argument, she described the process of understanding language as “analysis by synthesis.” This refers to the reproduction of a certain image or signal by using a model. In the case of meaning comprehension, language is the image that is projected by the language knowledge of the speaker and the listener. The actual comprehension or meaning generation comes down to the reproduction of the signals to one’s linguistic knowledge (Martin, 2020).

Once again returning to Ross’ *Mississippilessly* example of the introduction, language compositionality can be used as an explanation of why it is that humans are able to infer the

meaning of a novel compositional word which such ease. We have acquired the meaning of countless morphemes over a lifetime. After establishing and setting the meaning of these morphemes, we can use them to extract the meaning of the entire word and to combine them together into novel compositional words. However, even though this process of language compositionality partly answers the question of how humans infer and learn novel compositional word meaning, there is more to the story.

1.4 Language Processing

Let's take a step back. In order to practise the process of language compositionality, or to infer word meaning, humans have to process language. Language processing is a complicated and elaborate cognitive function that includes different types of information and abilities, both linguistic and non-linguistic (e.g., memory retrieval and executive control). Poirier and Shapiro (2012) described the language processing system as one that needs more research in order to be able to optimally understand it and its implications because it is only possible to examine the (essentially unobservable) language processing system with observable aspects (e.g., accuracy scores or reaction times). Therefore, as much research as possible should be done in order to find more empirically supported information that enables us to make generalisable and plausible claims about it (Poirier & Shapiro, 2012).

Similarly, Martin (2016) argued that more empirically tested information on language processing is needed with regard to the combination of psycholinguistic and neuroscientific language theories. She put forward the idea of cue integration as the link between psycholinguistic theories and neurobiological theories of language processing. For both frameworks, a *cue* is a piece of information that refers back to a certain aspect of the physical environment. Our brain uses these cues to build a perception which is subsequently used to act upon. For example, when someone hears a car horn whilst cycling, the car horn is a cue on

which the perception is built that that person should make way for the approaching car. According to Martin (2016), language processing and comprehension are processes that combine cue integration and cue combination. The latter entails – as its name suggests – the combination of, and interaction between, multiple cues. These cues could be from different modalities (e.g., spoken, textual, image, gestural, etc.) and may provide complementary information on which a perception can be built. For example, when someone's name is being called, the information flows from a combination of auditory, visual, and gestural information. The actual spoken words tell us whose name is being called, and the volume and pitch of the caller's voice provide us additional information about their mood and intentions. Cue combination is followed by cue integration, which entails the interaction between cues of the same modality (Martin, 2016).

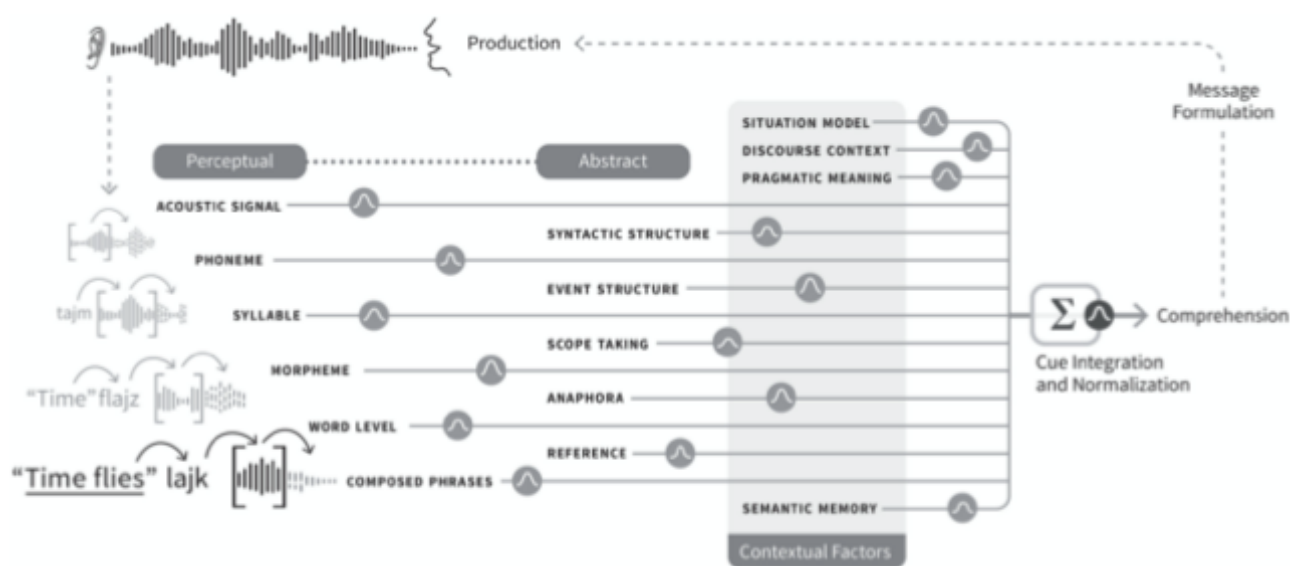
To link the cue integration theory back to language, it is advantageous to regard the predecessor of the proposed cue integration theory, which was called the Competition Model (CM). The CM, formulated by Bates and MacWhinney (1987), claimed that the way in which lexical information is expressed – by cues – differs between languages. In other words, the way in which words are shaped (i.e., how cues are formed) is different for each language. Thus, cues are representations of linguistic units, and the way in which these are used to build a perception to understand the word differs between languages. This links cue integration back to language, essentially by describing cue integrations as language processing (Bates & MacWhinney, 1987).

Building on the CM, Martin (2016) argued that a cue simply is a representation of a certain piece of linguistic information that relates to the aspect that it reflects. Put together, cues ensure sensory input to be processed into abstract representations. This is the essence of the Cue Integration Model, of which a graphical overview can be found below in Figure 1. As can be seen in this overview, cues from various levels are combined together and eventually

come to the surface as a certain linguistic representation (e.g., letter combinations, words, or phrases). Thus, cues are used to build linguistic representation, which is used to understand the physical world around us. This argument coincides with the aforementioned claim by Mahon and Caramazza (2008), who argued that words and meaning are inferred and subsequently used to understand the world around us.

Figure 1

Graphical representation of the Cue Integration Model of language processing (Adapted from Martin, 2016)



A more neurobiological account on language processing is put forward by Hagoort (2013). He divided language processing into three subdivisions: Memory, Unification, and Control (MUC). The first and only segment that is specific to language is Memory. This segment refers to all knowledge that is acquired during the course of a lifespan. For example, this knowledge is about sounds of certain words (phonology), the way in which sentences of a language are grammatically structured (syntax), or how certain conceptual building blocks could be combined together (morphology). All of this linguistic information is stored in the neocortex in our brain and can be retrieved as memories so that humans can use this information over and over when needed. Though, when looking back at the introduction's example of

Mississippilessly, it becomes clear that language processing must be more than just memory retrieval. In this case, Ross combined several previously acquired morphemes in a novel way. The fact that he is able to generate novel meaning shows that language processing is not all about the retrieval of memory structures. The derivation of novel compositional meaning is what the MUC Model refers to as Unification. Essentially, Unification regards the retrieval of previously acquired linguistic knowledge and subsequently using that to compose novel structures, which is exactly what Ross was able to do in his response to the spray-tan instructor. The last segment of the model is called Control and links language to (inter)actions of and between people. This regards executive control, which is the ability to conduct goal-directed behaviour. It thus features both linguistic knowledge and cognitive abilities (Hagoort, 2013).

The MUC Model argues for a different division of labour compared to its predecessor, the now obsolete neurobiological model of language processing called Wernicke Lichtheim Geschwind (WLG). The difference mainly regards to connections within the left perisylvian language cortex, which is the brain area that includes both Broca's area and Wernicke's area (Hagoort, 2013). Evidence in favour of the MUC Model was put forward by Snijders et al. (2008). They performed an fMRI study in which they investigated sentence comprehension of syntactic structures. Their experiment included sentences that contained ambiguous nouns and verbs, such as the Dutch word *vluchten*, which can either mean *flights* or *to flee*. This is an ambiguous word because participants could either interpret it as a noun (*flights*) or as a verb (*to flee*). In combination with sentences that contained unambiguous words (i.e., words that could not be interpreted as both a noun or a verb but just as one meaning), participants were asked to read the words whilst their brain activity was scanned. The results of the fMRI experiment showed that both brain areas that are relevant to previously mentioned Unification process should show a larger effect for sentences that contained ambiguous words in comparison to sentences that contained unambiguous words, because the left inferior frontal

cortex (LIFC) also contributes to the unification of syntactic structures. As Broca's area is situated in the LIFC, these results showed that this specific brain area plays a significant part in processing syntactic structures together with the left posterior middle temporal gyrus (MTG). In other words, whereas the classical WLG Model predicted that Broca's area only subserved language comprehension, these results showed that Broca's area also plays a role in language processing. Thus, the strict separation of Broca's area and Wernicke's area proposed by the WLG Model is rejected, proving the suggestions put forward by the MUC Model to be highly plausible (Snijders et al., 2008).

1.5(Abstract) Rule Learning

The aforementioned Unification process, regarding the retrieval of previously acquired linguistic knowledge and subsequently using that to compose novel structures, is linked to the fact that humans are able to instinctively infer the meaning of novel compositional words (like *Mississippilessly*). That is, humans use their previously acquired knowledge about the morphemes *Mississippi*, *-less*, and *-ly* in order to infer the meaning of the entire word. The question that remains unanswered for a large part, however, regards the computations that lie underneath this learning process, not only with regard to language learning but in general as well. As mentioned before, Martin (2020) argued that the meaning of compositional words is not only computed by the different constituent parts, but by the rules used to make the specific combinations as well. Thus, she advocates for the fact that humans should be aware of certain rules in the process of inferring and learning the meaning of novel compositional words. The question that stems from this is can humans in fact learn these (abstract) rules and subsequently use them to infer the meaning of novel structures? And if so, which rules do we use?

Collins and Frank (2016) proposed the Hierarchical Clustering Model, which argued that humans deduct and find structures in their surroundings, which are subsequently clustered

into sets of rules. These rule sets have a facilitating role in the repeated use of that acquired knowledge in new situations or novel contexts. Moreover, these rule sets are latent. In other words, the information of the rule set can be used in other contexts than the specific one in which it was acquired (Collins & Frank, 2016). For example, if someone learns how to phone someone with an Android mobile telephone, they are able to transfer that knowledge when using an Apple iPhone as well. Collins and Frank examined the hypothesis put forward by the Hierarchical Clustering Model with a learning experiment in which participants are exposed to visual input patterns after which they had to select one of four keys (of which one was correct). By means of this reinforcement feedback, participants learned which key they had to press for whenever they saw a piece of specific visual input. By means of an EEG analysis, it would become evident in the neural encoding of reward and/or error whether participants learned a latent structure and subsequently used it in other situations (i.e., transfer it to novel contexts). The results of their experiment revealed evidence in favour of this because participants' behaviour showed structure-learning patterns as generalisation and transfer of those patterns. Moreover, their findings indicated that even novel structures could be used as a cue that refers back to previously acquired knowledge (i.e., a specific rule set), allowing for an instantaneous transfer of that (latent) rule set to the novel situation or context, even if that novel context was never perceived or encountered before (Collins & Frank, 2016).

The most important follow-up question would be whether humans are able to apply similar rule sets in order to infer and learn novel word meaning.

1.6 The Present Study

The present study hopes to further our understanding of language processing by examining in more detail how humans infer and learn novel compositional word meaning as the result of derivational affixation. Therefore, the following research question is proposed: 'In what way

(i.e., with which learning strategy) do humans infer and learn novel compositional word meaning that is the result of derivational affixation?' The research question is examined through two behavioural experiments in which participants are taught compositional words using an artificial language, after which it is tested whether they can generalise that knowledge to other novel compositional words. These novel compositional words consist of a Dutch stem (one free morpheme) and a novel affix (one derivational bound morpheme) (e.g., *klahond* (ENG: *kladog*) meaning *puppy*). The main difference between two behavioural experiments is that the second is designed as such to ensure a deeper encoding of the meaning of the novel compositional words. This is mainly done through design differences in the first phase of the experiment (explained in more detail in the Methodology section).

Some additional information has to be provided about the design of the present study in order to be able to explain the hypotheses appropriately in the following section. There were three different ways in which the sequential order of the novel compositional words was constructed. Compared to the words the participants were introduced to in the first phase of the experiment, the order of the novel compositional words of the second phase of the experiment could either be order-congruent, order-incongruent, or a mismatch. Order-congruent novel compositional words were meaningful at the surface level (e.g., *hotkla* with suffix *kla* meaning *opposite of*). Order-incongruent words have an incongruent sequential order of the stem and the affix combination compared to the order-congruent novel compositional words that were learned during the first phase (e.g., *klahot* with prefix *kla* actually meaning *young version of* instead of the order-congruent *hotkla*). Mismatched words have a meaningless combination of stem and affix compared to those learned words (e.g., *klagrass* meaning *the young version of grass* and *grasskla* meaning *the opposite of grass*). This will be explained in more detail in the third section (Methodology).

To examine whether humans are able to apply similar rule sets as proposed by Collins and Frank (2016) in order to infer and learn novel word meaning, the present study formulated three different (abstract) rule learning strategies that will be further examined. These are referred to as the ASSO-strategy, the BLEND-strategy and the BUILD-strategy. In order to appropriately infer the intended meaning of the novel compositional words, humans have to be able to learn and apply two (abstract) rules, namely that of compositionality and the sequential order rule. ASSO-learners are called as such because they apply an *associative*, flat learning strategy that is comparable to vocabulary learning. They are neither aware of the compositionality of the words, nor the sequential order rule of the affix. Thus, they are not capable of learning certain (abstract) rules in order to infer the meaning of novel compositional words. BLEND-learners are named as such because they integrate the meanings of the different constituent parts together. In other words, even though they are aware of the compositionality, they *blend* the two meanings of the affix together without taking the sequential order rule into account. BUILD-learners are named as such because contrasting to BLEND-learners, they are aware of the sequential order rule. Therefore, they *build* the different conceptual blocks onto each other in order to infer and learn the meaning of novel compositional words.

2. Hypotheses

First of all, it is expected that there will be a difference between participants' response on the three different word types (order-congruent novel compositional words, order-incongruent novel compositional words, mismatched novel compositional words). See Hypothesis 1 for a more detailed prediction.

Hypothesis 1: Participants more often indicate that order-congruent novel compositional words have meaning compared to order-incongruent and mismatched novel compositional words. Additionally, participants more often indicate that order-incongruent novel compositional words have meaning compared to mismatched novel compositional words.

Additionally, it is expected that the different designs of Experiment 1 and Experiment 2 have an influence on participants' performance in the second phase of the experiment. See Hypothesis 2 for a more detailed prediction.

Hypothesis 2: Deep encoding of the meaning of order-congruent novel compositional words has an influence on participants' performance in the second phase of Experiment 2 as compared to the second phase of Experiment 1, at least in the sense that participants to a greater degree indicate that the order-congruent novel compositional words they are introduced to in the second phase of Experiment 2 have meaning compared to Experiment 1.

Furthermore, it is hypothesised that participants should use either (or both) of two main learning strategies, that will be referred to as the BLEND-strategy and the BUILD-strategy

throughout the present study. Moreover, a baseline is set to describe the behaviour of participants that are not able to infer and learn novel compositional word meaning, which is referred to as the ASSO-strategy. This is summarised in Hypothesis 3 (see below). An additional remark should be made about the phrasing of *learning strategies*, as it is possible that these, in practise, will show to be less like clear-cut strategies and more like developmental processes (as different stages could occur during learning).

If participants adopt the ASSO-strategy, they infer and learn the meaning of novel compositional words in a way that is similar to vocabulary learning on the surface, which is flat, associative learning. Therefore, they are not aware of the compositionality of the words, nor the sequential order rule of the affix. This should become evident from the results in the sense that ASSO-learners are in no way able to answer the affix questionnaire at the end of the learning phase.

If participants adopt the BLEND-strategy, they do take the (abstract) rule of compositionality of the novel word into account. However, they do not consciously take the sequential order rule into account. This should become evident from their answers on the affix questionnaire at the end of the first phase of the experiment: if they did not explicitly mention that the meaning of the novel compositional word is dependent on the place of the affix and/or if they in some cases only mentioned one meaning instead of two, because this indicates their possible lack of awareness.

If participants adopt the BUILD-strategy, they take both the compositionality of the novel word as the sequential order rule into account. In other words, they are able to learn both (abstract) rules to apply them the process of inferring the meaning of the novel compositional words. This should become evident from their answers on the affix questionnaire at the end of the first phase of the experiment in the way that they explicitly mentioned that the meaning of

the novel compositional word is dependent on the place of the affix for at least one of the meaning categories.

Hypothesis 3: *Participants use either the BLEND-strategy or the BUILD-strategy in order to infer and learn novel compositional word meaning. If participants are not able to infer and learn novel compositional word meaning, they adopt the ASSO-strategy.*

Following this, it is expected that the strategy that participants use to infer and learn novel compositional word meaning has an influence on their performance in the second phase of the experiment, with regard to which words they indicate as meaningful and which words they indicate as meaningless. It is predicted that the different learner types show different performance on the testing phase compared to each other. This is summarised in Hypothesis 4 (see below).

Participants that adopt the BLEND-strategy are predicted to indicate to a greater extent the order-incongruent novel compositional words to have meaning compared to BUILD-learners, because they are not aware of the sequential order rule of the novel compositional words. In other words, they are not aware of the (abstract) rule that the place of the affix has an influence on the meaning of the novel compositional word. For example, they will be able to successfully indicate the meaning of a word like *oldkla* to be *young*. However, if they would encounter the word *klaold*, they would also indicate the meaning to be *young*, as they do not consciously take the place of the affix into account in their process of meaning generation.

Participants that adopt the BUILD-strategy are predicted to be able to indicate the order-congruent novel compositional words to have meaning, and the order-incongruent and mismatched compositional words to not have meaning. Moreover, they will be able to successfully note the meaning of the new order-congruent novel compositional words. For

example, they will be able to successfully infer the meaning of a word like *oldkla* (order-congruent). Additionally, they will indicate that a word like *klaold* (order-incongruent) holds no meaning, as they are aware that the meaning is dependent on the place of the affix. This stems from the fact that they are able to learn both (abstract) rules about the construction of the novel compositional words: the compositionality as well as the sequential order rule. This results in the fact that they can successfully recognise which words have an intended meaning and which words do not. Therefore, BUILD-learners are expected to less often indicate that the order-incongruent novel compositional words have meaning in comparison to the BLEND-learners

Participants that adopt the ASSO-strategy are expected to indicate words of all types (order-congruent, order-incongruent, mismatched) to be meaningful less often compared to participants that use the BLEND-strategy or the BUILD-strategy. This is due to the fact that if participants received the information that *kladog* means *puppy*, they should be able to reproduce this knowledge. However, if they are asked to indicate the meaning of prefix *kla-* with a novel stem, such as *klachicken*, they will not be able to retrieve the correct meaning. This is due to the fact that they are not aware of any of the (abstract) rules about the construction of the novel compositional words: neither the compositionality of the word, nor the sequential order rule of the affix. Therefore, they will in no case be able to infer the meaning of the new novel compositional words that they are introduced to in the second phase of the experiment.

Hypothesis 4: *The strategy (BLEND-strategy and BUILD-strategy [or ASSO-strategy]) that participants use to infer and learn novel compositional words (either order-congruent, order-incongruent, and/or mismatched) has an influence on their performance in the testing phase.*

3. Methodology

The present study proposed the following research question: ‘In what way (i.e., with which learning strategy) do humans infer and learn novel compositional word meaning that is the result of derivational affixation?’ This was examined through two behavioural experiments that consisted of two word-learning phases in which participants were introduced to the novel compositional words. The words were either order-congruent (i.e., meaningful at the surface level, such as *hotkla* with suffix *kla* meaning *opposite of*), incongruent (i.e., not meaningful at the surface level because the sequential order of the stem and affix is incongruent, such as *klahot* instead of the order-congruent *hotkla*), or a mismatch (i.e., stem and affix combination is meaningless such as *klagrass*). The first and second experiment differed from each other on several aspects. This is explained in more detail below.

3.1 Participants

In total 40 participants performed the experiments. In Experiment 1, 20 participants participated, of which 10 were male and 10 were female. All participants that performed Experiment 1 were between 18-35 years old ($M = 25.82$, $SD = 4.98$, $Range = 16$). In Experiment 2, 20 participants participated, of which eight were male and 12 were female. All participants were Dutch native speakers and raised monolingually. The age range of the participants that participated in Experiment 2 was also between 18-35 years old ($M = 24.30$, $SD = 4.86$, $Range = 17$). All participants signed a consent form (see Appendix A) previous to the experiment and were rewarded a monetary compensation.

3.2 Materials

The experiment of the present study included a total of 120 semi-novel compositional words that consisted of a known Dutch stem that was either a noun or adjective (e.g., *dark*) in

combination with one of three pseudo-affixes with an attached meaning (e.g., prefix *kla* means *young version* and suffix *kla* means *opposite*), resulting in stimuli words such as *darkkla*. Thus, the exact meaning of the affix was dependent on its place i.e., whether it was a prefix or a suffix.

In order to generate the novel compositional words, a list of Dutch nouns and adjectives was gathered from the lexical database Celex (Piepenbrock & Gulikers, 1995). All stems were required to be of similar syllable length (maximum of three syllables) and frequency of the words was based on the judgement of a native speaker of Dutch to make sure all stimuli words are in fact known by Dutch native speakers. Additionally, the stems were selected to fit the six affix meaning categories.

In total, there were six different meaning categories. These were based on both existing affix meanings (e.g., meaning category *without* was based on the existing Dutch suffix *-loos*) and non-existing meanings (e.g., there is no existing Dutch affix that entails the meaning *colour of*). The six meaning categories were divided over three affix forms, namely *kla*, *ran*, and *ler*. Based on the results of Experiment 1, the meaning pairs for Experiment 2 were re-grouped due to some unintended responses. See Table 1 (next page) for an overview of all affix forms and meaning categories per experimental condition for both experiments and see Appendix B and Appendix C for a complete overview of the stimuli materials for both experiments.

In total, there were 30 learning-phase novel compositional words and the 90 testing-phase novel compositional words that belonged to either one of three experimental conditions: the order-congruent condition, the order-incongruent condition, or the mismatch condition.

The order-congruent condition included novel compositional words that are meaningful. The combination of the derivational affix and the stem for the order-congruent words all resulted in one straightforward meaning that could be summarised in one word. This was important because the participants had to be able to link the meaning representation of the

novel compositional word to one other clear-cut meaning in their mental lexicon, instead of to a description of the meaning. For example, prefix *kla* hold the meaning of *young version*, resulting in a word like *kladog* to mean *puppy*. In that way, participants could learn that *kladog* means *puppy*, instead of that *kladog* means *the young version of dog*. Therefore, all order-congruent novel compositional words were paired with a Dutch synonym that was the resulting meaning of the affix-stem combination (such as *puppy* for *kladog*). These synonyms were required to be words that did not consist of a combination of a stem and affix. For example, for a word like *ranhouse* (prefix *ran* meaning *without*) a fitting synonym with regard to the meaning would be *homeless*, however, the word *homeless* is a combination of the stem *home* plus the affix *less*, which was not allowed.

Order-incongruent novel compositional words were, as their name suggests, incongruent with the words in the learning phase in terms of sequential order (e.g., *klahot* instead of the order-congruent word *hotkla*). These order-incongruent words could be meaningless (e.g., *klahot* meaning *the small version of hot*, but can also be meaningful when the sequential order rule is not taken into account (e.g., *klahot* meaning *the opposite of hot* when *kla* hold the meaning of *opposite* or *young version* irrespectively of the place of the affix). The order-incongruent words were necessary to examine if participants are able to learn (abstract) rules in order to infer and learn novel compositional word meaning. That is, the order-congruent words implicitly show that there is a sequential order rule (i.e., the place of the affix influences its meaning). By swapping the place of the affix for the order-incongruent words, it can be examined whether participants are aware of the sequential order rule or not. This shines light on their specific learning strategy, and thus on how exactly they infer and learn the meaning of novel compositional words.

It was ensured that the mismatch novel compositional words could not be meaningful in either order combination. In other words, whether the stem is combined with the prefix or

the suffix, the meaning should not make any sense. Thus, in the mismatch condition, affix *kla* is combined with stems that have no meaningful outcome in any way. For example, *klagrass* means *the young version of grass* and *grasskla* means *the opposite of grass*. The mismatch condition was used as a check because participants should not be able to figure out any meaning of any of stimuli words that belong to the mismatch condition. See Table 1 (next page) for an overview of all affix forms and meaning categories per experimental condition for both experiments.

The final grouping of meaning categories using the same affix form (e.g., *kla* meaning either *young version* and/or *opposite*) was based on clarity and straightforwardness in order to prevent participants to be confused during learning. In order to establish whether the meaning categories and the stimuli words were comprehensible enough and if the stimuli words fitted the three conditions properly, three pilots were conducted¹. These three pilots were computed in Word-documents and send out via email. All participants were students at the Radboud University Nijmegen.

¹ These pilots were conducted as part of the internship.

3.2.1 Pilot 1

Pilot 1 was conducted in order to find out whether participants would come up with the same or similar synonyms for the stimuli words. In this pilot, participants were first presented to the meaning of a certain affix form, followed by two example synonyms. Using this information, the participants had to come up with three synonyms for the remaining eight items per meaning category. The pilot was filled in by five participants with an age range between 22 and 25 years old ($M = 23$, $SD = 1$, $Range = 2$). Four participants identified as female and one participant identified as non-binary. All items were randomised as such that every participant came across different examples and different items, resulting in the fact that the stimuli words were all tested an equal number of times. In other words, the order of the meaning-categories as well as the order of the individual stimulus items differed per participant. It was made sure that prefix and suffix alternated each other and the two meanings that belonged to the same affix form (*kla*, *ler*, or *ran*) did not follow each other directly.

Novel compositional words that showed to be ambiguous or unclear according to the results were replaced from the stimuli list, or their corresponding synonym was altered slightly. For example, the stimuli word *volkla* (*vol* + *kla*) was often misinterpreted as *volk* (ENG: nation) instead of *vol* (ENG: full). Therefore, the stimuli word was changed to *leegkla* (*leeg* + *kla*) in order to prevent the confusion.

3.2.2 Pilot 2

Pilot 2 was conducted in order to find out whether participants were able to come up with the intended meanings of the affix forms. Here, participants were presented with five novel compositional words with their corresponding synonym. According to this information, participants had to deduct the meaning of the affix in order to see whether the meaning they indicated would be similar to or the same as the meaning that was set by the researcher. The

pilot was filled in by five different participants with an age range between 22 and 27 years old ($M = 24.2$, $SD = 1.9$, $Range = 5$). One participant identified as male and four participants identified as female. The six meaning categories alternated each other, but the prefix/suffix meanings of the same affix form did not follow each other directly. The order was randomised for each participant.

The results indicated that almost all meaning categories were clear as the participants named the same meaning in (almost) all cases.

3.2.3 Pilot 3

Pilot 3 was conducted in order to find out whether participants could infer the meaning of the affix dependent on its place. To do this, participants were given ten novel compositional words with their corresponding meaning, both stems combined with a prefix as stems combined with a suffix. In other words, whereas participants that filled in Pilot 1 or Pilot 2 were introduced to the six meaning categories individually, participants that participated in Pilot 3 were introduced to the three affix forms individually. Subsequently, participants were asked to use those ten words to come up with the meaning(s) of the affixes. Ideally, participants would come up with two meanings per affix form. This pilot was filled in by five participants with an age range between 21 and 26 years old ($M = 22.6$, $SD = 2.1$, $Range = 5$). One participant identified as male and four participants identified as female.

The results of pilot 3 showed that two out of five participants in all cases explicitly mentioned that the meaning difference is caused by the place of the affix, showing knowledge about the underlying structure of the novel compositional word. Two other participants never explicitly mentioned that the meaning difference is caused by the place of the affix, and also in some cases 'failed' to deduct the correct meaning. One participant explicitly mentioned the place of the affix only for the last affix form in the pilot.

After aforementioned three pilots, the stimuli list was optimised and used for Experiment 1. Subsequently, the results of the first experiment were used to adjust and optimise the stimuli for Experiment 2 (described into more detail below).

3.3 Procedure

Both Experiment 1 and Experiment 2 were developed with Gorilla, an online experiment builder (Anwyl-Irvine et al., 2019). All participants were recruited through Prolific, a website that provides self-service data collection (www.prolific.co).

A cover story about a recently discovered community that speaks a foreign language was composed to make the experiment more natural to the participants. See Appendix D for the exact instruction and story.

3.3.1 Experiment 1

In the first part (the Learning Phase) of Experiment 1 (see Figure 2) participants were introduced to the meaning of the first 30 order-congruent novel compositional words. These words with their corresponding meaning subsequently appeared on their screen. The words automatically succeeded each other after 10.000 ms, however, participants were able to proceed to the next word by clicking a *next* button on their screen. The order in which the words appeared was randomised per participant. Subsequently, participants were asked to fill in a questionnaire that contained of three questions about the meaning of the unknown word parts (the affixes). There was no limit for this questionnaire. The importance of the place of the affix was not mentioned in the question, in order to see whether participants would explicitly touch upon this themselves or not. The final affix questionnaire contained the same three questions previously mentioned and included an overview of the 30 novel compositional words with their

corresponding meanings. In Experiment 1, the order in which the meaning of the affixes was asked was fixed (i.e., the same for every participant) for both questionnaires.

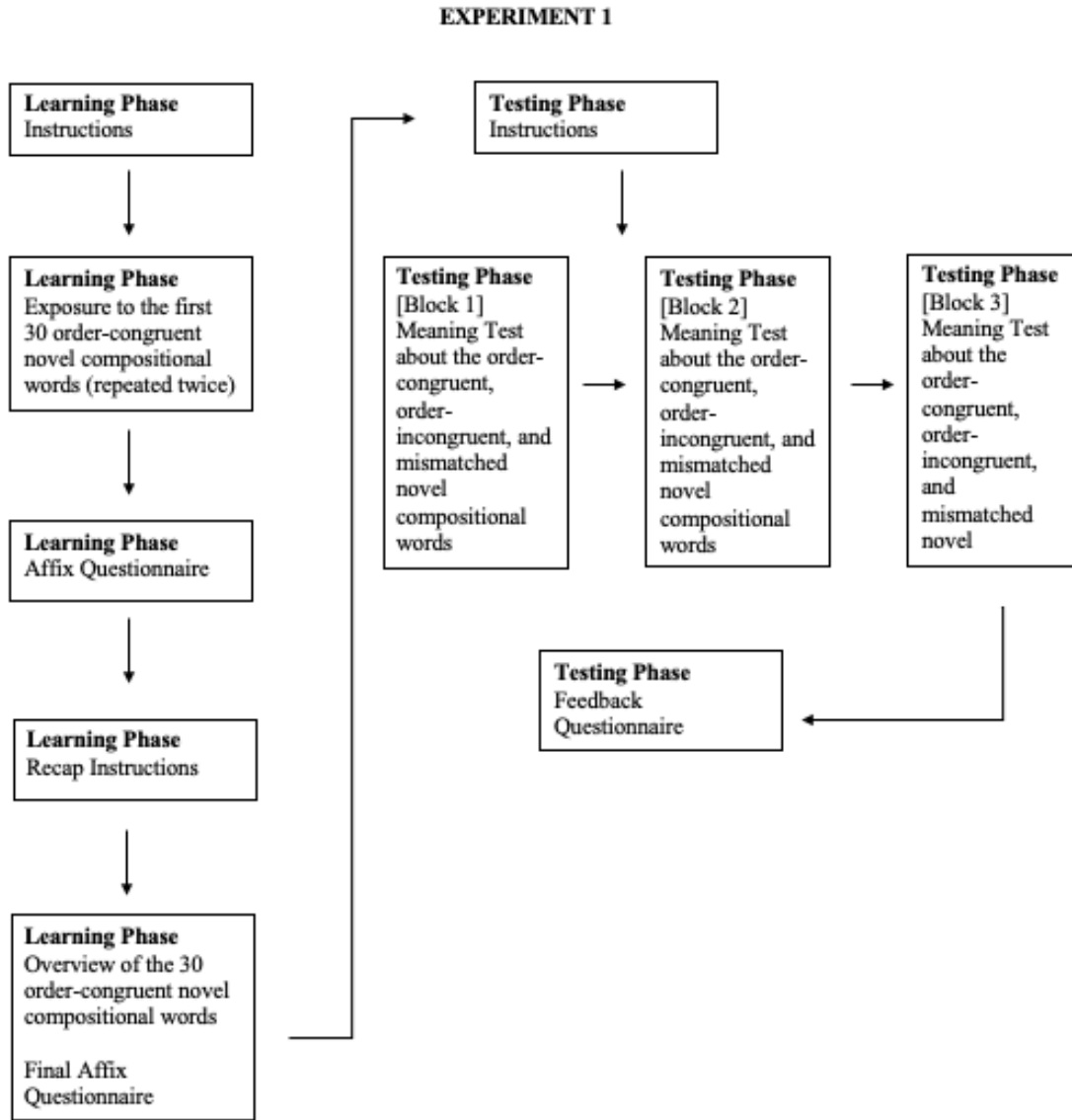
In the second phase (the Testing Phase) of Experiment 1 (see Figure 2) participants were introduced to the words that were congruent in order compared to the novel compositional words that were learned in the learning phase (henceforth: learned words)², the words that were incongruent in order compared to the learned words, and the mismatched words. These words were divided three blocks and shown to the participants in randomised order. Each block included ten words from each condition to assure that the stimuli words were equally divided. Then the order of items per block per participant was randomised. After reading a novel compositional word, participants were asked to state its meaning in a comment box below the question. There was no time limit to finish this task.

The duration of Experiment 1 varied across participants, with an average of 38 minutes, ranging from 21 to 59 minutes.

² Additionally, three other order-congruent compositional words were included in the Testing Phase trial for the prefix *ran* (meaning 'without') condition, in order to compare participants' responses with the original stimuli for this condition, to possibly update the stimuli list for Experiment 2.

Figure 2

Depiction of the schema for Experiment 1.



3.3.2 Experiment 2

Similar to Experiment 1, Experiment 2 was conducted to examine how humans infer and learn novel compositional word meaning. However, contrary to Experiment 1, the design of the learning phase of Experiment 2 was developed to ensure a deeper encoding of the novel compositional word meaning in order to find out whether that had an influence on the performance in the testing phase. Therefore, Experiment 2 differed from Experiment 1 in several aspects. First of all, the design of Experiment 2 was changed to ensure that the participants had deeper encoding of the word meaning. This was mainly done through changes in the Learning Phase, which are explained below.

In the first part (the Learning Phase) of Experiment 2 (see Figure 3), participants were introduced to the first 30 order-congruent novel compositional words. Instead of only showing the novel compositional word with its corresponding meaning as in Experiment 1, an example sentence was shown for each novel compositional word. The example sentence allowed the participants to obtain additional information, such as word class and how meaning can be embedded in a sentence context. All sentences were high constraint (i.e., the sentence context was semantically logical and fitting to the novel compositional word). See Appendix E for an overview of all sentences. The novel compositional words with corresponding example sentence automatically succeeded each other after 15.000 ms, however, participants were able to proceed to the next word by clicking a *next* button on their screen. After having read the 30 novel compositional words with their corresponding meanings and example sentences, participants entered a task in which they had to answer 30 multiple-choice questions about the meaning of the novel compositional words they had just been introduced to. The question contained the meaning of the novel compositional words, and the participants had to choose between four answer possibilities to indicate which of the words corresponded to the meaning in the question. For example, they were asked: 'Which of the following words means *girl*?'.

The answer possibilities of which they could choose were systematically drawn up as follows. All 30 novel compositional words were paired so that the pairs contained two novel compositional words with different affix forms. The place of the affix (i.e., either prefix or suffix) could either be the same or different within the pairs. The answer possibilities were drawn up according to these pairs, and consisted of the correct meaning, the paired stimuli word, and a combination of the stems and affixes of the paired stimuli words. For example, the answer possibilities of aforementioned question were: *klawoman*, *randrinks*, *ranwoman*, *kladrinks*. See Appendix F for an overview of the answer possibilities. There was no time limit to finish this task. The learning blocks and the subsequent memory task was repeated three times in order to make sure that the participants remembered all the words. The order in which the novel compositional words with their corresponding meanings and example sentences were presented to the participants were randomised for each block. Similarly, the order of the answer possibilities was randomised for each question. The paired stimuli words differed per task i.e., the novel compositional words were paired with other novel compositional words for each task.

Another difference between Experiment 1 and Experiment 2 was that the stimuli words of the latter were optimised as such that the meaning categories *strong version* and *colour of* were swapped. This was done because the results of Experiment 1 indicated that some participants were confused about the meaning category combination of *strong version* and *without*. As the meaning category of *strong version* showed to be the most confusing, it was chosen to combine it with the meaning category that was proven most straightforward according to the answers of Experiment 1, which was *colour of*. Second, the stimuli materials were slightly altered with regard to the mismatch condition. Due to the swap of the meaning categories, baseline matching turned out to be more difficult as in some cases no complete meaningless combinations could be made. The words that were unable to fit into the mismatch condition were combined with a new affix form *sen*. No additional meaning was matched to

this affix form, as it only functioned as a solution to appropriately match all stimuli words in the mismatch condition.

After the third learning phase task, participants had to fill in a questionnaire about the meaning of the affixes that was similar to the one of Experiment 1, only in the case of Experiment 2, the order in which the meaning of the affixes was asked was randomised instead of fixed. At the end of the learning phase, the accuracy in the memory task reached between 90% and 100% ($M = 98.3$, $SD = 2.7$, $Range = 10$).

In the Testing Phase participants were introduced to the words that were congruent in order compared to the novel compositional words that were learned in the learning phase (henceforth: learned words), the words that were incongruent in order compared to the learned words, and the mismatched words. The Testing Phase of Experiment 2 was similar to the Testing Phase of Experiment 1, except for the fact that the words that the participants were introduced to in the learning phase were also included in the testing phase. These were evenly divided between the three trials, resulting in each trial to consist of 40 items (10 words per condition) in randomised order. Coinciding with Experiment 2, a short feedback questionnaire followed the testing phase.

The duration of Experiment 2 varied across participants, with an average of 47 minutes, ranging from 27 to 136 minutes.

3.4 Analysis

The present study used several variables in order to examine the hypotheses and find an answer to the research question, 'In what way (i.e., with which learning strategy) do humans infer and learn novel compositional word meaning that is the result of derivational affixation?' The independent variables were condition type (the order-congruent condition, the order-incongruent condition, mismatch condition), experiment number (either Experiment 1 or 2), affix form (i.e., *kla*, *ran*, and *ler*), meaning category, and learner type. Participants were assigned to be either BLEND-learners or BUILD-learners according to their answers on the final affix questionnaire of the learning phase. A participant was categorised as a BLEND-learner if they did not explicitly mention that the meaning of the novel compositional word is dependent on the place of the affix and/or if they in some cases only mentioned one meaning instead of two. If a participant explicitly mentioned this for at least one of the categories, they were categorised as a BUILD-learner.

The first dependent variable was answer on the testing phase trials. This was either based on whether participants considered the items to be meaningful (ANSWER_MEANING) or based on whether participants had reported the expected meaning when they indicated the item to be meaningful (ANSWER_CORRECT). The participants' answers were coded as follows. For ANSWER_MEANING, participants' answers were quantified to a 1 when they indicated that the specific novel compositional word had meaning and quantified to a 0 when they indicated that the specific novel compositional word had no meaning. For ANSWER_CORRECT, participants' answers were quantified to a 1 when they indicated that an item had meaning and if they indeed stated the correct meaning and quantified to a 0 when they indicated that an item had no meaning or if they indicated that an item had meaning but stated the wrong meaning. For example, for the target word *heetkla* (with suffix *kla* meaning *opposite*), a participant's answer was quantified to a 1 when they indicated that the word had meaning and that the meaning was

cold. However, some participants indicated that the word meant *warm*. In that case, their answer was quantified to a 0. The two answer scores were averaged per participant per condition. Following this, the average answer scores were values that showed the degree to which a participant had indicated that the words belonging to a certain condition either had meaning (if their average answer scores were close to 1) or had no meaning (if their average answer scores were close to 0).

Separately for Experiment 1 and Experiment 2, it was investigated whether the average answer scores (ANSWER_MEANING and ANSWER_CORRECT) differed between the different experimental conditions. Several aspects would become clear by examining this, depending on the condition. The average answer scores for the order-congruent condition and the order-incongruent condition would provide information about the way in which participants learn and infer the meaning of novel compositional words. The mismatch condition (and the learning phase stimuli words only for Experiment 2) served as a check whether the participants had understood the assignment correctly. Following this, participants' average answer scores on each of the experimental conditions were compared with each other to examine the contrast between the different conditions.

Combining the data of Experiment 1 and Experiment 2, two main analyses were performed. First, a between-experiment comparison was conducted in order to find out whether there is a difference between the average answer scores (ANSWER_MEANING and ANSWER_CORRECT) for the different experiment versions. This analysis would provide more information about whether the different learning phases of Experiment 1 and Experiment 2 (i.e., whether the deep encoding of the second experiment) had an influence on participants' performance in the testing phase. Additionally, this would shed light on whether it is able to combine the data from both experiments for the analysis explained below. Second, it was investigated whether the average answer scores (ANSWER_MEANING and ANSWER_CORRECT)

differed between learner type (either BLEND-learner or BUILD-learner). The two experiments were combined to get more power given the rather small number of participants in each experiment. By combining the results of the two experiments, light was shed on whether there is an interaction between the way in which participants infer meaning of novel structural words and their performance in the testing phase.

The data from Experiment 1 and Experiment 2 were analysed with the statistical package IBM SPSS (version 24.0). There were no missing values in the data set. No data were excluded.

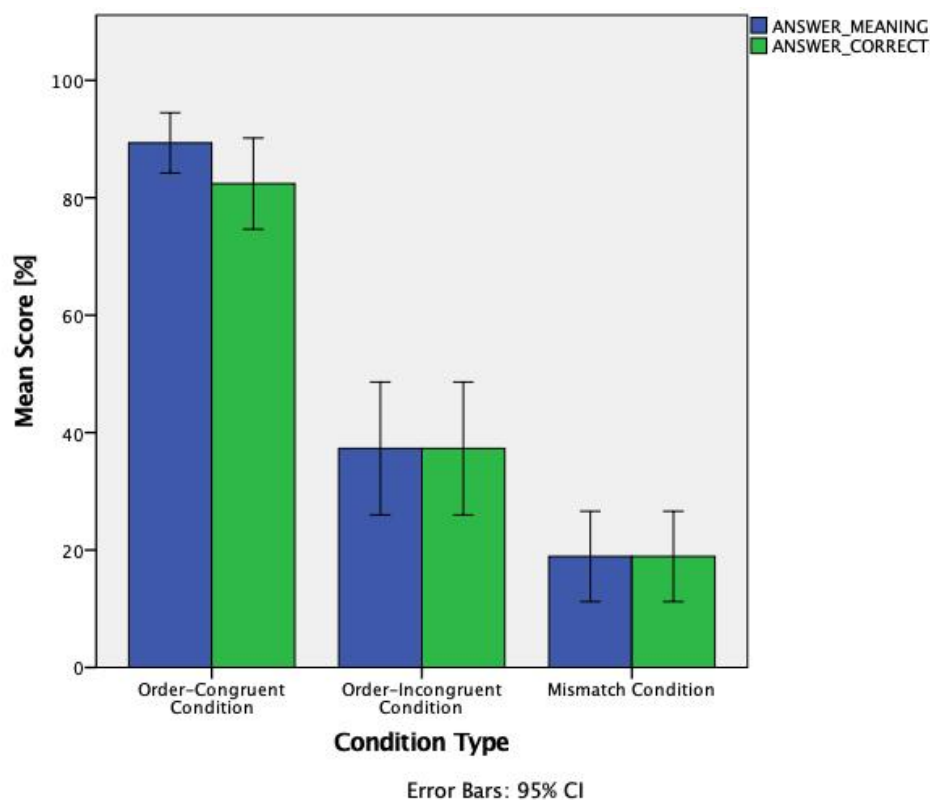
4. Results

4.1 Experiment 1

Experiment 1 was carried out to examine how humans infer and learn novel compositional word meaning. For ANSWER_MEANING (i.e., based on whether participants considered the items to be meaningful) the participants reported 89% ($SD = 0.11$) of the words from the order congruent condition to be meaningful. Additionally, participants reported 37.3% ($SD = 0.24$) of the words from the order incongruent condition to be meaningful. Moreover, participants reported 18.8% ($SD = 0.16$) of the words from the baseline condition to be meaningful. For ANSWER_CORRECT (i.e., based on whether participants had reported the expected meaning when they indicated the item to be meaningful) the participants reported 82.3% ($SD = 0.17$) of the words from the order congruent condition to be meaningful. Additionally, participants reported 37.3% ($SD = 0.24$) of the words from the order incongruent condition to be meaningful. Lastly, participants reported 18.8% ($SD = 0.16$) of the words from the baseline condition to be meaningful. See Figure 4 (next page) for an overview of the average answer scores (both ANSWER_MEANING and ANSWER_CORRECT) for the three conditions.

Figure 4

Participants' performance for the three experimental conditions (order-congruent, order-incongruent, mismatch) for Experiment 1. ANSWER_MEANING indicates whether participants consider the items to be meaningful. ANSWER_CORRECT indicates whether participants have reported the expected meaning when they indicated the item to be meaningful.



For ANSWER_MEANING, a repeated measures ANOVA with a Greenhouse-Geisser correction³ showed that there was a statistically significant effect of condition type on average answer score for the three conditions, $F(2, 38) = 108.28, p < 0.001$. The effect of condition type represented the fact that the order-congruent condition was significantly different from the order-incongruent condition $F(1, 19) = 64.34, p < 0.001$, the order-congruent condition was significantly different from the mismatch condition, $F(1, 19) = 308.54, p < 0.001$, and the order-incongruent condition was significantly different from the mismatch condition, $F(1, 19) =$

³ Mauchly's Test of Sphericity indicated that the assumption of sphericity had been violated, $\chi^2(2) = 12.22, p = 0.002$. Therefore, a Greenhouse-Geisser correction was used.

21.56, $p < 0.001$. See Figure 4 (blue bars) for a visualisation of the ANSWER_MEANING scores per condition type.

For ANSWER_CORRECT, a repeated measures ANOVA with a Greenhouse-Geisser correction⁴ showed that there was a statistically significant effect of condition type on average answer score for the three conditions, $F(2, 38) = 63.52, p < 0.001$. The effect of condition type represented the fact that the order-congruent condition was significantly different from the order-incongruent condition, $F(1, 19) = 34.38, p < 0.001$, the order-congruent condition was significantly different from the mismatch condition, $F(1, 19) = 155.25, p < 0.001$, and the order-incongruent condition was significantly different from the mismatch condition, $F(1, 19) = 21.56, p < 0.001$. See Figure 4 (green bars) for a visualisation of the ANSWER_CORRECT scores per condition type.

4.2 Experiment 2

Contrary to Experiment 1, the design of the learning phase of Experiment 2 was developed to ensure a deeper encoding of the novel compositional word meaning in order to find out whether that had an influence on the performance in the testing phase. Moreover, the stimuli words from the learning phase were also included in the testing phase of Experiment 2, which was not the case in Experiment 1. The results were again used to compute two different average answer scores per condition for every participant, either based on whether participants considered the items to be meaningful (ANSWER_MEANING) or based on whether participants had reported the expected meaning when they indicated the item to be meaningful (ANSWER_CORRECT). These were used to calculate general averages for the four conditions

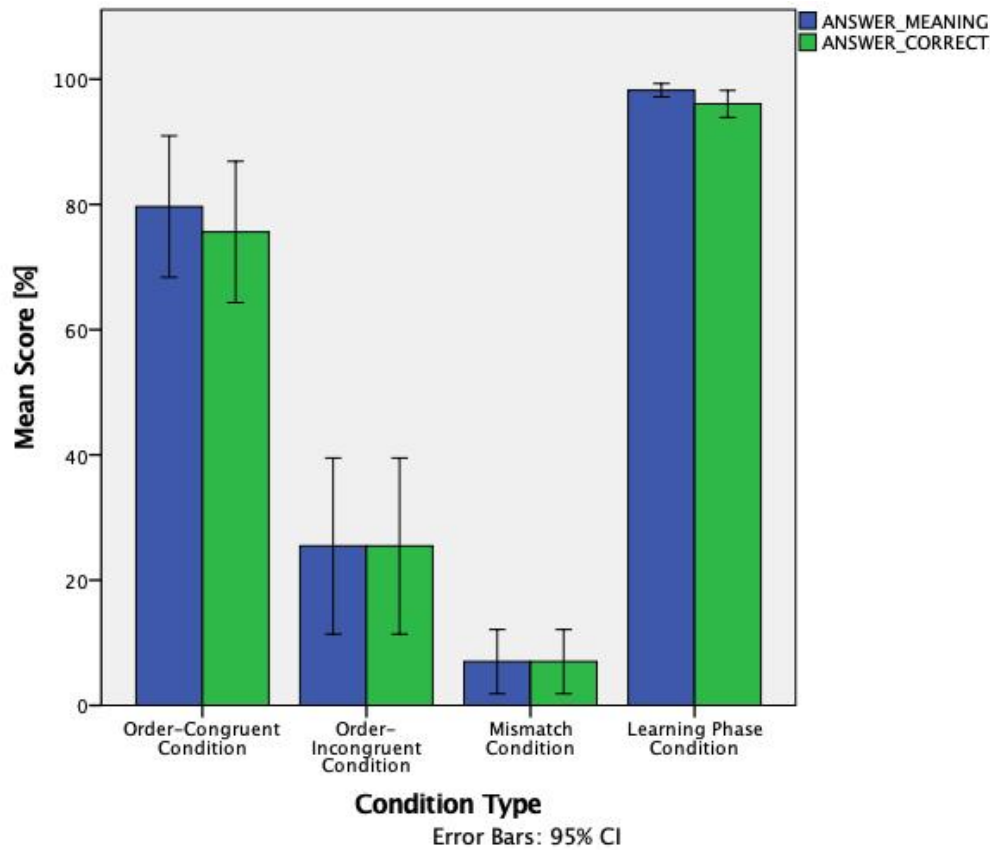
⁴ Mauchly's Test of Sphericity indicated that the assumption of sphericity had been violated, $\chi^2(2) = 16.34, p < 0.001$. Therefore, a Greenhouse-Geisser correction was used.

(order congruent condition, order incongruent condition, mismatch condition, and the learning phase words).

For ANSWER_MEANING, the participants reported 80% ($SD = 0.24$) of the words from the order-congruent condition to be meaningful. Additionally, participants reported 25% ($SD = 0.30$) of the words from the order-incongruent condition to be meaningful. Moreover, participants reported 7% ($SD = 0.11$) of the words from the baseline condition to be meaningful. Lastly, participants reported 98% ($SD = 0.02$) of the words from the learning phase condition to be meaningful. For ANSWER_CORRECT, the participants reported 76% ($SD = 0.24$) of the words from the order-congruent condition to be meaningful. Additionally, participants reported 25% ($SD = 0.30$) of the words from the order-incongruent condition to be meaningful. Moreover, participants reported 7% ($SD = 0.11$) of the words from the baseline condition to be meaningful. Lastly, participants reported 95% ($SD = 0.06$) of the words from the learning phase condition to be meaningful. See Figure 5 for an overview of the average answer scores (both ANSWER_MEANING and ANSWER_CORRECT) for the four conditions.

Figure 5

Participants' performance for the four experimental conditions (order-congruent, order-incongruent, mismatch, learning phase) for Experiment 2. ANSWER_MEANING indicates whether participants consider the items to be meaningful. ANSWER_CORRECT indicates whether participants have reported the expected meaning when they indicated the item to be meaningful.



For ANSWER_MEANING, a repeated measures ANOVA with a Greenhouse-Geisser correction⁵ showed that there was a statistically significant effect of condition type on average answer score for the three conditions, $F(3, 57) = 107.27, p < 0.001$. The effect of condition type represented the fact that the order-congruent condition was significantly different from the order-incongruent condition $F(1, 19) = 46.80, p < 0.001$, the order-congruent condition was significantly different from the mismatch condition, $F(1, 19) = 176.84, p < 0.001$ and the order-

⁵ Mauchly's Test of Sphericity indicated that the assumption of sphericity had been violated, $\chi^2(5) = 25.01, p < 0.001$. Therefore, a Greenhouse-Geisser correction was used.

congruent condition was significantly different from the learning phase condition $F(1, 19) = 12.03, p = 0.003$. Moreover, the order-incongruent condition was significantly different from the mismatch condition, $F(1, 19) = 10.22, p < 0.001$, and the order-incongruent condition was significantly different from the learning phase condition, $F(1,19) = 108.06, p < 0.001$. Additionally, the mismatch condition was significantly different from the learning phase condition, $F(1, 19) = 1313.62, p < 0.001$.

For ANSWER_CORRECT, a repeated measures ANOVA with a Greenhouse-Geisser correction⁶ showed that there was a statistically significant effect of condition type on average answer score for the three conditions, $F(3, 57) = 107.27, p < 0.001$. The effect of condition type represented the fact that the order-congruent condition was significantly different from the order-incongruent condition, $F(1, 19) = 46.80, p < 0.001$, the order-congruent condition was significantly different from the mismatch condition, $F(1, 19) = 176.84, p < 0.001$, and the order-congruent condition was significantly different from the learning phase condition, $F(1, 19) = 12.03, p < 0.003$. Moreover, the order-incongruent condition was significantly different from the mismatch condition, $F(1, 19) = 10.23, p < 0.001$, and the order-incongruent condition was significantly different from the learning phase condition, $F(1, 19) = 108.06, p < 0.001$. Additionally, the mismatch condition was significantly different from the learning phase condition, $F(1, 19) = 1312.62, p < 0.001$. See Figure 5 (green bars) for a visualisation of the ANSWER_MEANING scores per condition type.

4.3 Experiment Version and Condition Type

As mentioned before, the design of the learning phase of Experiment 2 was developed to ensure a deeper encoding of the novel compositional word meaning in order to find out whether that

⁶ Mauchly's Test of Sphericity indicated that the assumption of sphericity had been violated, $\chi^2(5) = 25.01, p < 0.001$. Therefore, a Greenhouse-Geisser correction was used.

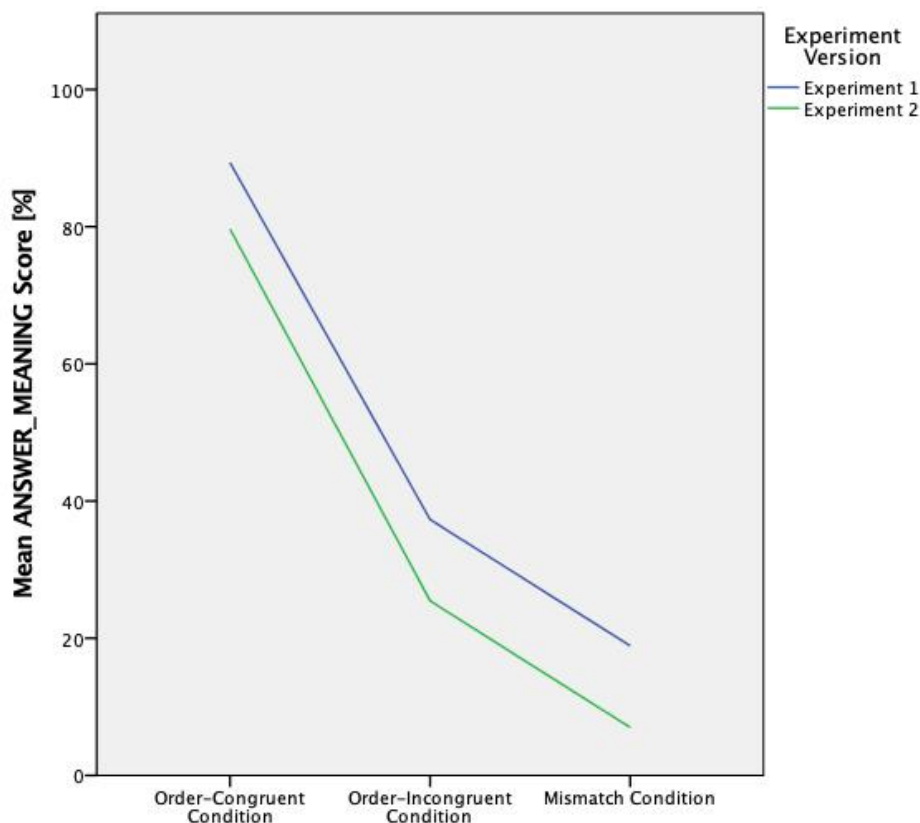
had an influence on the performance in the testing phase. A mixed ANOVA was conducted to further examine whether there is difference in participants' performance (i.e., their average answer scores on the three conditions) depending on which experiment they have performed.

For ANSWER_MEANING, a mixed ANOVA with a Greenhouse-Geisser correction⁷ indicated that the effect of experiment version was significant, $F(1, 38) = 5.84, p = 0.021$. Moreover, there was a significant main effect of condition type, $F(2, 76) = 165.59, p < 0.001$. The effect of condition type represented the fact that the order-congruent condition was significantly higher than the order-incongruent condition $F(1, 38) = 27.74, p < 0.001$, the order-congruent condition was significantly higher than the mismatch condition $F(1, 38) = 107.61, p < 0.001$, and the order-incongruent condition was significantly higher than the mismatch condition $F(1, 38) = 445.72, p < 0.001$. Moreover, there was no significant interaction between condition type and experiment version, $F(2, 76) = 0.051, p = 0.909, ns$. See Figure 6 for visualisation.

⁷ Mauchly's Test of Sphericity indicated that the assumption of sphericity had been violated $\chi^2(2) = 14.566, p = 0.001$. Therefore, a Greenhouse-Geisser correction was used.

Figure 6

ANSWER_MEANING performance between Experiment Version (Experiment 1 and Experiment 2) for the three condition types (order-congruent condition, order-incongruent condition, and mismatch condition). Data combined from Experiment 1 and Experiment 2.



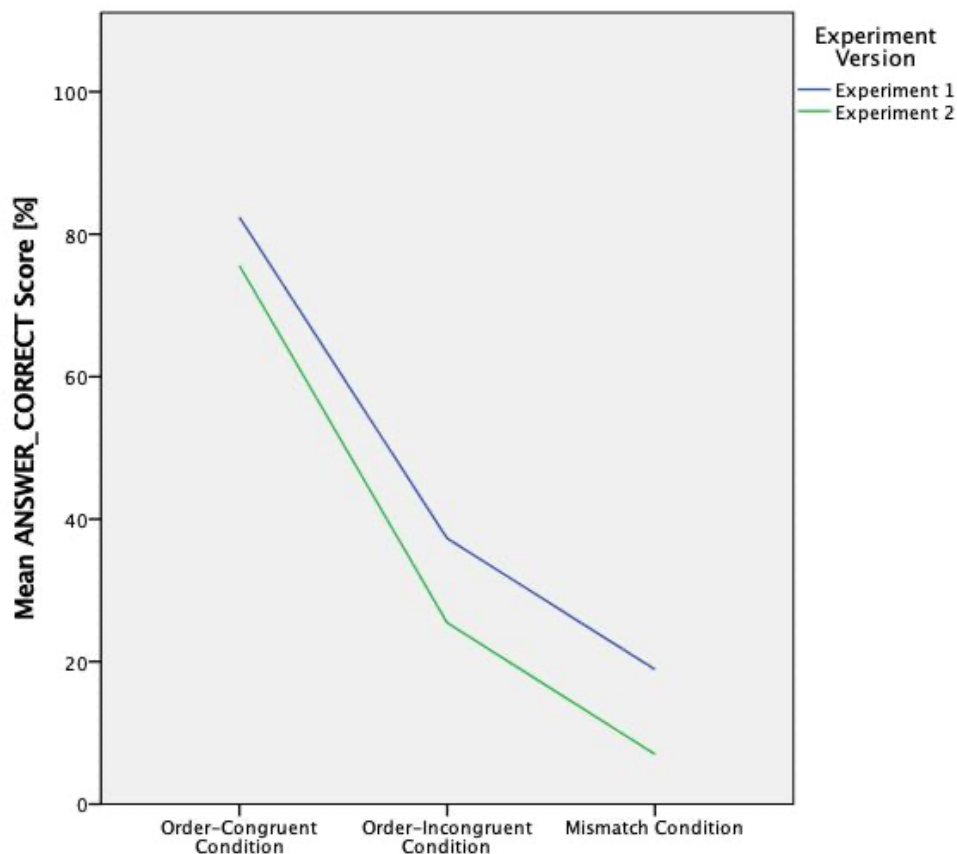
For ANSWER_CORRECT, a mixed ANOVA with a Greenhouse-Geisser correction⁸ indicated that the effect of experiment version was significant, $F(1, 38) = 5.25, p = 0.028$. Moreover, there was a significant main effect of condition type, $F(2, 76) = 117.58, p < 0.001$. The effect of condition type represented the fact that the order-congruent condition was significantly higher than the order-incongruent condition $F(1, 38) = 70.95, p < 0.001$, the order-congruent condition was significantly higher than the mismatch condition $F(1, 38) = 290.11, p < 0.001$, and the order-incongruent condition was significantly higher than the mismatch condition $F(1,$

⁸ Mauchly's Test of Sphericity indicated that the assumption of sphericity had been violated $\chi^2(2) = 17.862, p < 0.001$. Therefore, a Greenhouse-Geisser correction was used.

38) = 27.74, $p < 0.001$. Additionally, there was no significant interaction between condition type and experiment version, $F(2, 76) = 0.231, p = 0.722, ns$. See Figure 7 for visualisation.

Figure 7

ANSWER_CORRECT performance between Experiment Version (Experiment 1 and Experiment 2) for the three condition types (order-congruent condition, order-incongruent condition, and mismatch condition). Data combined from Experiment 1 and Experiment 2.



4.4 Learner Type and Condition Type

As previous paragraph indicated, there was no significant interaction effect between experiment version and condition type. Therefore, the results from Experiment 1 and Experiment 2 were combined together to investigate whether the different type of learners (BLEND-learners and BUILD-learners) have behaved differently on the three experimental

conditions. In order to make an appropriate comparison, the fourth condition (learning phase words) of Experiment 2 were not taken into regard for this analysis.

Based on their answers on the final affix questionnaire of the learning phase, participants were categorised to either BLEND-learners or BUILD-learners. For Experiment 1, 8 participants (40%) were categorised as BLEND-learners and 12 participants (60%) were categorised as BUILD-learners. For Experiment 2, 15 participants (75%) were categorised as BLEND-learners and 5 participants (25%) were categorised as BUILD-learners.

A mixed ANOVA was conducted to see whether different type of learners would behave differently on the three experimental conditions (order-congruent condition, order-incongruent condition, mismatch condition).

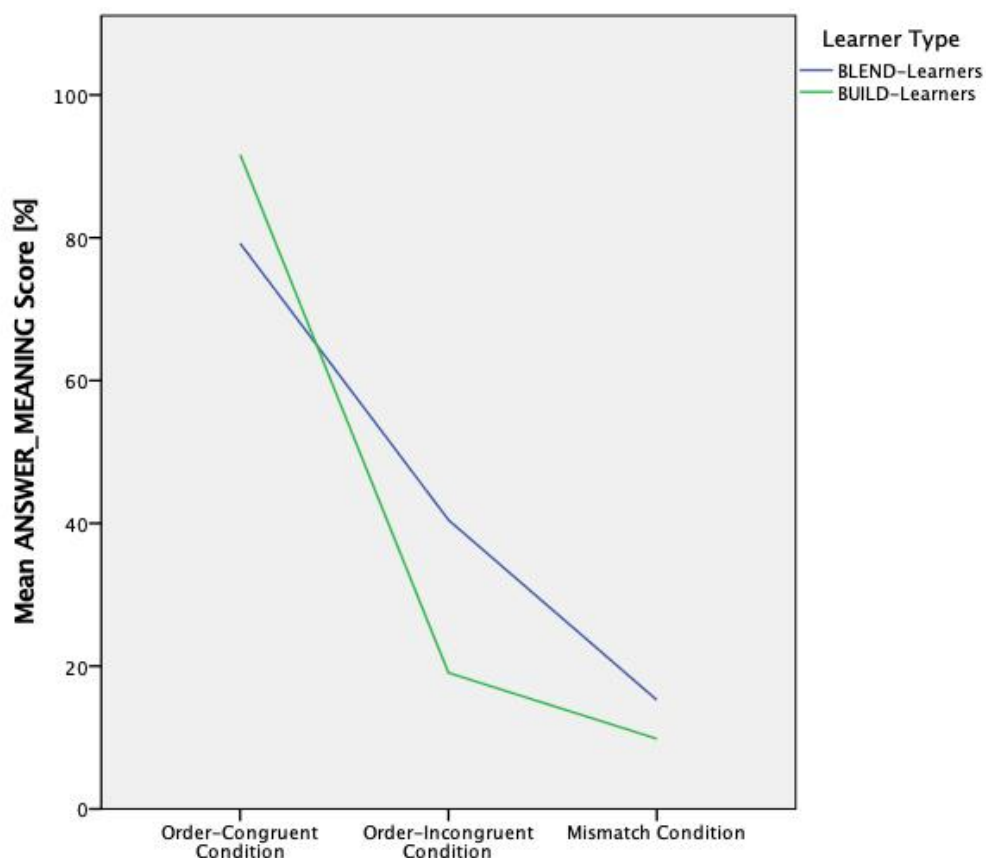
For ANSWER_MEANING, a mixed ANOVA with a Greenhouse-Geisser correction⁹ indicated that the effect of learner type was not significant, $F(1, 38)$, $p = 0.333$, *ns*. However, there was a significant main effect of condition type, $F(2, 76) = 219.03$, $p < 0.001$. The effect of condition type represented the fact that the order-congruent condition was significantly higher than the order-incongruent condition, $F(1,38) = 161.41$, $p < 0.001$, the order-congruent condition was significantly higher than the mismatch condition, $F(1, 38) = 549.29$, $p < 0.001$, and the order-incongruent condition was significantly higher than the mismatch condition, $F(1, 38) = 27.4$, $p < 0.001$. Moreover, there was a significant interaction between condition type and learner type, $F(2, 76) = 10.96$, $p < 0.001$. In order to examine the way in which the two learner types performed differently in each of the conditions, three independent samples *t*-tests were performed between the two learner types. For the order-congruent condition, an independent samples *t*-test indicated that there was no significant difference between the answers of BLEND-learners ($M = 0.79$, $SD = 0.23$) and BUILD-learners ($M =$

⁹ Mauchly's Test of Sphericity indicated that the assumption of sphericity had been violated, $\chi^2(2) = 8.34$, $p = 0.015$. Therefore, a Greenhouse-Geisser correction was used.

0.92, $SD = 0.10$), $t(38) = 2.13$, $p = 0.057$, 95% CI = [0.01, 0.24], *ns*. For the order-incongruent condition, an independent samples t -test indicated that there was a significant difference between the answers of BLEND-learners ($M = 0.41$, $SD = 0.32$) and BUILD-learners ($M = 0.19$, $SD = 0.04$), $t(38) = -2.61$, $p < 0.001$, 95% CI = [-0.38, -0.05]. For the mismatch condition, an independent samples t -test indicated that there was a significant difference between the answers of BLEND-learners ($M = 0.15$, $SD = 0.18$) and BUILD-learners ($M = 0.10$, $SD = 0.08$), $t(38) = -1.13$, $p = 0.008$, 95% CI = [-0.15, 0.04]. See Figure 8 for visualisation.

Figure 8

ANSWER_MEANING performance of different learner types (BLEND-learners and BUILD-learners) for the three condition types (order-congruent condition, order-incongruent condition, and mismatch condition). Data combined from Experiment 1 and Experiment 2.

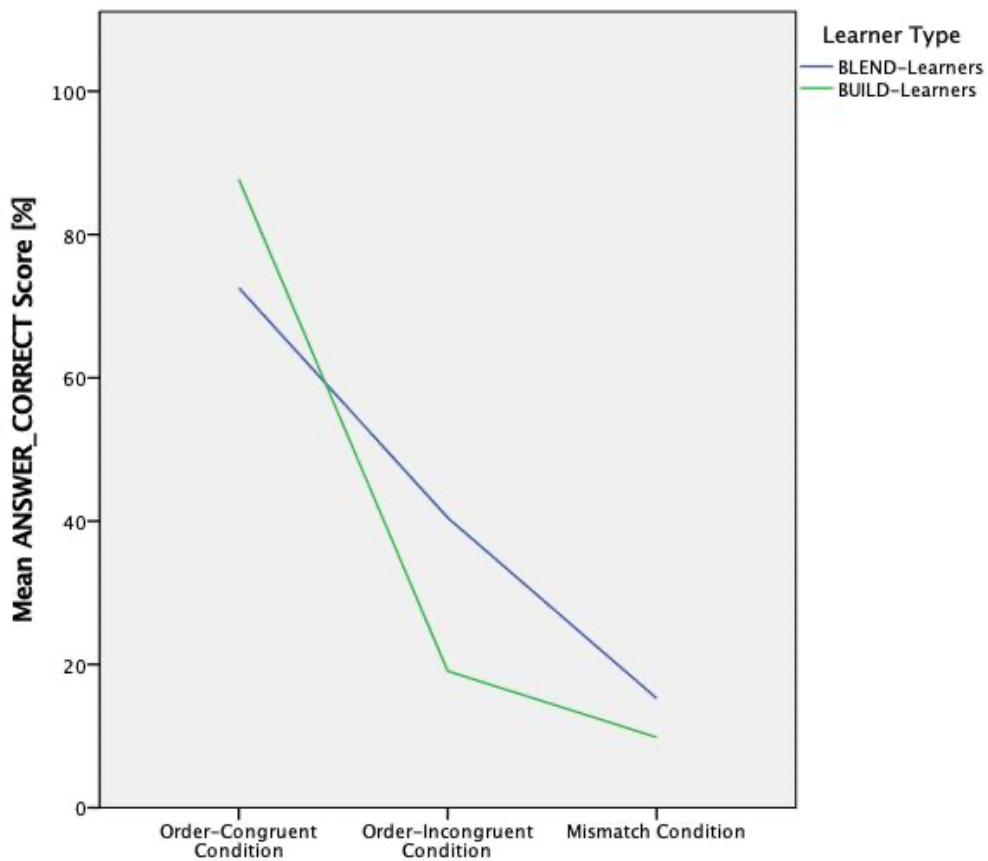


For ANSWER_CORRECT, a mixed ANOVA with a Greenhouse-Geisser correction¹⁰ indicated that the effect of learner type was not significant, $F(1, 38)$, $p = 0.408$, *ns*. However, there was a significant main effect of condition type, $F(2, 76) = 155.39$, $p < 0.001$. The effect of condition type represented the fact that the order-congruent condition was significantly higher than the order-incongruent condition, $F(1, 38) = 105.80$, $p < 0.001$, the order-congruent condition was significantly higher than the mismatch condition, $F(1, 38) = 357.35$, $p < 0.001$, and the order-incongruent condition was significantly higher than the mismatch condition, $F(1, 38) = 27.41$, $p < 0.001$. Moreover, there was a significant interaction between condition type and learner type, $F(2,76) = 10.67$, $p < 0.001$. In order to examine the way in which the two learner types performed differently in each of the conditions, three independent samples *t*-tests were performed between the two learner types. For the order-congruent condition, an independent samples *t*-test indicated that there was no significant difference between the answers of BLEND-learners ($M = 0.73$, $SD = 0.22$) and BUILD-learners ($M = 0.88$, $SD = 0.15$), $t(38) = -2.40$, $p = 0.34$, 95% CI = [-0.28, -0.03] *ns*. For the order-incongruent condition, an independent samples *t*-test indicated that there was a significant difference between the answers of BLEND-learners ($M = 0.41$, $SD = 0.32$) and BUILD-learners ($M = 0.19$, $SD = 0.14$), $t(38) = 2.61$, $p < 0.001$, 95% CI [0.05, 0.38]. For the mismatch condition, an independent samples *t*-test indicated that there was a significant difference between the answers of BLEND-learners ($M = 0.15$, $SD = 0.18$) and BUILD-learners ($M = 0.10$, $SD = 0.08$), $t(38) = 1.13$, $p = 0.008$, 95% CI [-0.04, -0.15]. See Figure 9 for visualisation.

¹⁰ Mauchly's Test of Sphericity indicated that the assumption of sphericity had been violated $\chi^2(2) = 11.234$, $p = 0.004$. Therefore, a Greenhouse-Geisser correction was used.

Figure 9

ANSWER_CORRECT performance of different learner types (*BLEND*-learners and *BUILD*-learners) for the three condition types (order-congruent condition, order-incongruent condition, and mismatch condition). Data combined from Experiment 1 and Experiment 2.



5. Discussion

The present study examined in what way (i.e., with which learning strategy) humans infer and learn novel compositional word meaning that is the result of derivational affixation. This was done with two behavioural experiments that consisted of two phases. In the first phase, participants were taught novel compositional words with their corresponding meanings. In the second phase, it was tested whether participants could infer the meaning of unlearned novel compositional words based on their knowledge about the novel compositional words they had learned in the first phase. In order to do that, participants were introduced to words that were either order-congruent, order-incongruent or mismatched with the words they had learned during the learning phase. This was to test which of the hypothesised strategies (the ASSO-strategy, the BLEND-strategy, and/or the BUILD-strategy) they adopted in the process of inferring and learning novel compositional word meaning. In total, 40 participants took part in either Experiment 1 or Experiment 2. In order to test the hypotheses, two different answer scores per condition for every participant were computed. This was either based on whether participants considered the items to be meaningful (ANSWER_MEANING) or based on whether participants had reported the expected meaning when they indicated the item to be meaningful (ANSWER_CORRECT). These were used to calculate general averages for the three conditions (order-congruent condition, order-incongruent condition, and the mismatch condition). It turned out that these two answer scores generally pointed towards the same conclusion as the difference between the numbers for ANSWER_MEANING and ANSWER_CORRECT were highly similar within each condition¹¹. Therefore, this chapter will only focus on the first (i.e., whether participants indicated that the novel compositional words had meaning or not) for both the order-incongruent and mismatch condition, and on both (i.e., whether participants indicated

¹¹ For Experiment 1, there was a positive correlation between ANSWER_MEANING and ANSWER_CORRECT, $r = 0.98$, $n = 60$, $p < 0.001$. For Experiment 2, there was a positive correlation between ANSWER_MEANING and ANSWER_CORRECT, $r = 0.97$, $n = 80$, $p < 0.001$.

that the novel compositional words had meaning or not and whether they indicated the intended meaning) for the order-congruent condition.

In the current chapter, a discussion will be presented in terms of the four hypotheses that were constructed, as well as some limitations and implications of the present study, and suggestions for future research.

5.1 Hypothesis 1: Order-congruent words are more likely to be seen as meaningful.

Hypothesis 1 argued that participants more often indicate that order-congruent novel compositional words have meaning compared to order-incongruent and mismatched novel compositional words. Additionally, it was predicted that participants more often indicate that order-incongruent novel compositional words have meaning compared to mismatched novel compositional words.

By analysing the difference between the order-congruent, order-incongruent, and mismatched novel compositional words it became evident how often participants indicated the target words to have meaning in Experiment 1. More specifically, when the target word was congruent in order compared to the novel compositional words that were learned in the learning phase (henceforth: learned words) (e.g., *shortkla* with suffix *kla* meaning *opposite*, as learned in the learning phase), participants were more likely to judge it to be meaningful compared to words that were order-incongruent compared to the learned words (e.g., *klashort*) or mismatched in order compared to the learned words (e.g., *shortler* with suffix *ler* meaning *colour of*). Overall, participants indicated in a very high number of cases (90%) that the order-congruent words had meaning and slightly less cases (82%) also indicated the intended meaning. This shows that participants are, to a large extent, able to use previously acquired knowledge about the construction and meaning of novel compositional words (from the learning phase) to infer and learn the meaning of novel compositional words in the testing

phase. Moreover, this reflects the participants' ability to take the sequential order of the novel compositional words into account during the process of inferring the meaning.

When the target word was order-incongruent compared to order of the learned words, participants less often judged it to be meaningful compared to the order-congruent words, and more often judged it to be meaningful compared to the mismatched words. Overall, participants indicated below change level (37%) that the order-congruent words had meaning.

The target words that were mismatched compared to the order of the learned words were meaningless in every way and predominantly served as a control to see whether participants randomly answered during the testing phase. They were indicated to be meaningful the least number of times compared to the words that were congruent with the learned words and incongruent with the learned words. Overall, participants only sometimes (18%) judged the mismatched words to be meaningful. This could, first of all, indicate that they filled in a response that is more or less related to the target word. For example, one participant interpreted the mismatched compositional word *lerhigh* (which means *person who engages in high*) as *bungeejump*. This shows that they filled in a random response that is somewhat related to the word *high*. Second of all, it could indicate that some of the mismatched novel compositional words could actually be interpreted as meaningful. For example, some of the participants interpreted the mismatched compositional word *ransport* (which means *without sport*) as *rest*. This shows that they interpreted the word as meaningful, whereas the word was meant to be meaningless.

Experiment 2 can be considered as a replication study of Experiment 1. It differed from Experiment 1 in the sense that the learning phase was constructed in order to ensure a deeper encoding of the novel compositional word meaning. Moreover, the novel compositional words of the learning phase were also added in the testing phase of the experiment.

An analysis of the difference between the average answer scores on the different word types showed that there was a difference between how often participants indicated that the novel compositional words had meaning (and whether they correctly indicated the intended meaning) between those word types. More specifically, when the target word was congruent in order compared to the learned words, participants were more likely to judge it to be meaningful compared to words that were order-incongruent compared to the order of the learned words and mismatched compared to the order of the learned words. However, participants were slightly less likely to judge the unlearned order-congruent words to be meaningful compared to the learned words. Overall, participants indicated in a high number of cases (80%) that the order-congruent words had meaning and in slightly less of the cases (74%) indicated the intended meaning. Again, this shows that participants are, to a large extent, able to use previously acquired knowledge about the construction and meaning of novel compositional words (from the learning phase) to infer and learn the meaning of novel compositional words in the testing phase. This as well again reflects the participants' ability to take the sequential order of the novel compositional words into account during the process of inferring the meaning.

When the target word was order-incongruent compared to the order of the learned words, participants less often judged it to be meaningful compared to both the learned and unlearned order-congruent words. However, participants more often judged it to be meaningful compared to the mismatched words. Overall, participants indicated the order-congruent words to have meaning in a quarter of the cases.

The mismatched words again served as a control to see whether participants did not randomly answer during the testing phase. Similar to Experiment 1, the mismatched words were indicated to be meaningful the least often compared to both the learned and unlearned congruent words and the words that were incongruent with the learned words. Overall,

participants rarely (7%) judged the mismatched words to be meaningful. This could, first of all, indicate that they filled in a response that is more or less related to the target word. For example, one participant interpreted the mismatched compositional word *klakitchen* (which means *young version of kitchen*) as *scullery*. This shows that they filled in a response that is somewhat related to the word *kitchen*. Second of all, it could indicate that some of the mismatched novel compositional words could actually be interpreted as meaningful. For example, some of the participants interpreted the mismatched compositional word *ranleft* (which means *without left*) as *right*. This shows that they interpreted the word as meaningful, whereas the word was meant to be meaningless.

The learning phase words were judged to be meaningful the most often compared to all other word types, as participants in almost every case (95%) judged the learned order-congruent words to be meaningful and even indicated the intended meaning in almost all cases (94%). This shows that participants were able to learn the meaning of the words during the learning phase and were also able to reactivate this knowledge to infer their meaning in the testing phase.

Interim summary: Aforementioned results show that the order-congruent words are more likely to be seen as meaningful compared to the order-incongruent words or mismatched words. This reflects the participants' ability to detect the compositionality of the target words, and moreover, their ability to take the sequential order rule of the target words into account when inferring their corresponding meaning. Though, as the order-incongruent words are in some cases judged to be meaningful as well, it is possible that participants are not always aware of the sequential order rule of the affixation that takes place.

5.2 Hypothesis 2: The influence of a deep encoding of the meaning of novel compositional words

It was expected that the different designs of Experiment 1 and Experiment 2 would have an influence on participants' performance in the second phase of the experiment. More specifically, Hypothesis 2 argued that deep encoding of the meaning of order-congruent novel compositional words has an influence on participants' performance in the second phase of Experiment 2 as compared to the second phase of Experiment 1, at least in the sense that participants to a greater degree indicate that the order-congruent novel compositional words they are introduced to in the second phase of Experiment 2 have meaning compared to Experiment 1.

An analysis of difference in participants' performance (i.e., whether they indicated that the order-congruent and order-incongruent novel compositional words had meaning) depending on which experiment they had performed was carried out in order to examine this hypothesis. It turned out that there was a significant main effect of experiment type, indicating that overall, there was a difference between Experiment 1 and Experiment 2 with regard to the degree in which participants indicated that the unlearned novel compositional words had meaning. However, by comparing participants' performance in Experiment 1 and Experiment 2 separately for the different word types, it turned out that there was no significant interaction effect. In other words, the degree in which participants indicated that the unlearned order-congruent words had meaning, and the degree to which participants subsequently indicated the intended meaning of those words did not differ between Experiment 1 and Experiment 2. The degree to which participants indicated that the unlearned target words that were incongruent with the order of the learned words were meaningful did not differ between Experiment 1 and Experiment 2 either.

Even though these results are not entirely in favour of Hypothesis 2, this is not an indication of the absence of the facilitating role of a deeper encoding of meaning for learning novel compositional word meaning. It could very well be the case that the design of the learning phase of Experiment 1 was already sufficient enough to infer and learn the novel compositional words in order to appropriately use that acquired knowledge in novel situations (the testing phase), resulting in the fact that there was no difference between Experiment 1 and Experiment 2 with regard to the degree to which participants indicated the order-congruent and order-incongruent words to be meaningful.

Interim Summary: Overall, there was a difference between Experiment 1 and Experiment 2 with regard to the extent to which participants indicated the different word types to be meaningful. Although, the degree to which participants indicated that the unlearned order-congruent words and the unlearned order-incongruent words had meaning did not differ between Experiment 1 and Experiment 2.

5.3 Hypothesis 3: Participants' behaviour indicates the implementation of the BLEND-strategy as well as the BUILD-strategy

It was predicted that if participants are able to infer novel compositional word meaning, they would use the BLEND-strategy and/or the BUILD-strategy in order to do so. More specifically, Hypothesis 3 argued that if participants are able to infer and learn novel compositional word meaning, they adopt the BLEND-strategy and/or the BUILD-strategy in order to do so. BLEND-learners are able to learn the (abstract) rule of compositionality and apply it in the process of inferring and learning novel compositional word meaning, however, they are not aware of the sequential order rule. Therefore, they do not explicitly mention the place of the affix in the affix questionnaire. BUILD-learners take both the (abstract) rules of

compositionality and the sequential order rule into account in the process of inferring and learning novel compositional word meaning. Therefore, they explicitly mention the influence of the place of the affix in the affix questionnaire for at least one affix form. Additionally, the ASSO-strategy was proposed as baseline to describe what would happen if participants are not able to infer and learn novel compositional word learning. According to the ASSO-strategy, participants infer and learn the meaning of novel compositional words in a way that is similar to vocabulary learning on the surface, which is flat, associative learning. Following this, Hypothesis 3 also stated that ASSO-learners are not able to learn the (abstract) rule of compositionality nor the sequential order of the novel compositional words and will therefore not be able to answer the questions of the affix questionnaire.

In order to test the aforementioned hypothesis, affix questionnaire was analysed without using statistical tests. It became evident that none of the participants were completely unable to answer those questions. This could indicate that none of the participants adopted the ASSO-strategy i.e., all participants were able to infer and learn novel compositional word meaning and they were all aware of at least one of the (abstract) rules about the construction of the novel compositional words. In order to confirm this, the answers on the testing phase were also investigated. As explained before, the flat associative learning strategy of ASSO-learners would result in the fact that ASSO-learners would not be able to infer the correct meaning. This is due to the fact that the novel compositional words in the testing phase were not accompanied with a corresponding meaning. It indeed turned out that none of the participants were unable to infer the meaning of the unlearned order-congruent novel compositional words in the testing phase.

For Experiment 1, eight participants (40%) were categorised as BLEND-learners and 12 participants (60%) were categorised as BUILD-learners. For Experiment 2, 15 participants

(75%) were categorised as BLEND-learners and five participants (25%) were categorised as BUILD-learners.

When looking at this division it quickly becomes evident that it differs quite a bit. It could have been the case that the specific design of Experiment 1 had an influence on the (relatively) high number of BUILD-learners. In Experiment 1, participants were shown an overview of the order-congruent novel compositional words of the testing phase whilst simultaneously answering the affix questionnaire. In order to appropriately test the influence of the deep encoding of meaning in Experiment 2, the participants were not shown such an overview during the affix questionnaire. In other words, participants that participated in Experiment 1 could use an overview of the order-congruent novel compositional words whilst answering the affix questionnaire, whereas participants that participated in Experiment 2 could not. Therefore, it could have been easier for Experiment 1 participants to fill in the affix questionnaire, that was subsequently used to assign participants to a learner type. To account for this possibility, Experiment 2 participants were more often exposed to the order-congruent novel compositional words in the learning phase, however, the design difference could still be visible in the results in the way that more participants were categorised as BUILD-learners in Experiment 1.

A glance at the testing phase responses also showed that participants used both BLEND-learner and BUILD-learner behaviour. For example, participants indicated that the words have meaning for quite a number of the order-incongruent novel compositional words (37% in Experiment 1 and 25% in Experiment 2). This points towards the implementation of the BLEND-strategy. BLEND-learners are aware of the fact that the novel compositional word is composed of two parts (a stem and an affix), however, they are not aware that the place of the affix has an influence on its meaning. The order-incongruent novel compositional words were incongruent in terms of sequential order of the stem and affix (i.e., the order of the affix

and stem was swapped) as compared to order-congruent novel compositional words. For example, instead of *kladog* (prefix *kla* meaning *young version*), order-incongruent novel compositional words were constructed as *dogkla* (suffix *kla* actually meaning *opposite*). If participants would adopt the BLEND-strategy, they would not take the sequential order of the affix into account, resulting in the fact that they would interpret a word like *dogkla* as young version of dog as well. Following this, they would indicate the order-incongruent novel compositional words to have meaning, which is what happened in 37% (Experiment 1) and 25% (Experiment 2) of the cases for the order-incongruent novel compositional words. Therefore, this is a good indicator that (some of the) participants have adopted the BLEND-strategy. Though, it is important to take into consideration that the indication of order-incongruent novel compositional words to be meaningful could also have been a memory effect. In other words, participants could have been aware of the fact that the place of the affix had an influence on the meaning of the word, however, they could have forgotten whether the specific affix was a prefix or a suffix in the learning phase.

Mirroring the aforementioned logic, the fact that participants in more than half of the cases did (correctly) indicate that the order-incongruent novel compositional words do not have meaning is again a good indicator that participants have adopted the BUILD-strategy, because they are aware of the (abstract) rule that the novel compositional word is composed of two parts (a stem and an affix), and they are also aware of the fact that the place of the affix has an influence on its meaning (i.e., sequential order rule)

Interim summary: Neither the answers on the affix questionnaire nor the performance in the testing phase of both experiments suggested the implementation of the ASSO-strategy. This indicates that all participants were able to infer and learn novel compositional word meaning. Moreover, the answers on the affix questionnaire and a general examination of the behaviour

of the different learner types in performance on the novel compositional words in the testing phase of both experiments suggested the presence of both BLEND-learner and BUILD-learner behaviour.

5.4 Hypothesis 4: Similarities and differences between BLEND-learners and BUILD-learners' performance.

Hypothesis 4 stated that the strategy that participants use to infer and learn novel compositional words has an influence on their performance in the testing phase. Most importantly, BLEND-learners are able to infer the meaning of the new order-congruent novel compositional words they are introduced to after the first phase of the experiment. However, they will assign meaning to the order-incongruent words by inferring their meaning in the same way as order-congruent words. Thus, they will indicate to a greater extent that order-incongruent words have meaning as compared to BUILD-learners. BUILD-learners are able to successfully make a distinction between order-congruent novel compositional words and order-incongruent and mismatched novel compositional words in the sense that they will be able to successfully indicate the meaning of the order-congruent novel compositional words and dismiss the order-incongruent and mismatched novel compositional words. Thus, they less often indicate that the order-incongruent words have meaning as compared to BLEND-learners. Furthermore, a baseline for ASSO-learners was set, stating that ASSO-learners are not able to infer the meaning of unlearned novel compositional words they are introduced to after the learning phase.

Given that all participants have demonstrated the ability to infer and learn the meaning of novel compositional words and thus that they are aware of the (abstract) rules of the construction of the novel compositional words, clear evidence is provided that there are no purely associative learners (ASSO-learners) in the present experiment. Therefore, the

discussion will focus on how BLEND-learners and BUILD-learners performed differently on each type of novel compositional words (i.e., order-congruent, order-incongruent, and mismatched). With regard to the order-congruent novel compositional words, the results indicated that BLEND-learners as BUILD-learners were both able to use the knowledge they had acquired during the testing phase of the experiment to infer the meaning of other order-congruent novel compositional words they came across in the testing phase of the experiment. More specifically, BLEND-learners in 73% of the cases indicated that the target word had meaning as compared to 88% of the BUILD-learners.

The order-incongruent words are constructed as such that they are meaningful when the sequential order role is not taken into account (e.g., *klashort* (as compared to the order-congruent word *shortkla* with suffix *kla* meaning *opposite*)). When the target word was incongruent in order with the learned words, it turned out that BLEND-learners and BUILD-learners clearly differ in the degree to how often they indicate that the target word has meaning. More specifically, BLEND-learners in 41% cases indicated that the words had meaning as compared to 19% for the BUILD-learners. This is probably due to the fact that BLEND-learners are predicted to not take the sequential order of the novel compositional words into account.

With regard to the words that were mismatched compared to the learned words (and meaningless in any case), BLEND-learners and BUILD-learners differed in the extent to how often they indicated that the target words had meaning. More specifically, the BLEND-learners in 15% of the cases indicated that the mismatched words had meaning as compared to 10% of the BUILD-learners. These performance differences can be accounted for by the fact that if BLEND-learners did not take the sequential order rule into account, they may have interpreted some of the mismatch novel compositional words as meaningful because they had more loose requirements for inferring their meaning compared to BUILD-learners. For example, some of

the BLEND-learners interpreted the mismatched compositional word *klaesson* (which would be *young version* of *lesson*) as short lesson. This shows that they more loosely interpreted the meaning of *young version* so that it fitted the stem it was combined with, whereas the word was meant to be meaningless. It could however be that this is more due to of the specific choice of stimuli words rather than difference between BLEND-learners and BUILD-learners.

Interim Summary: The results show that BLEND-learners and BUILD-learners infer the meaning of order-congruent novel compositional words to a similar degree. This shows that both learner types are aware of the compositionality of the target words and that they can use this knowledge in order to infer and learn the meaning of unlearned novel compositional words. However, it turned out that BLEND-learners more often than BUILD-learners indicate that the target words that are incongruent compared to the learned words are meaningful. This is due to the fact that BLEND-learners to a lesser extent take the sequential order of the novel compositional words into account. Similarly, BLEND-learners more often than BUILD-learners indicate that the target words that are mismatched compared to the learned words are meaningful.

5.5 Limitations

The present study used the answers of the affix questionnaire to categorise participants to be either the BLEND-learners or BUILD-learners (or ASSO-learners). Subsequently, this division between the types of learners is used for several analyses throughout the study. However, the fact that the order in which participants were asked about the meaning of the affixes was not randomised for Experiment 1 could have had an influence on the results of the affix questionnaire because contrary to Experiment 1, this was ensured in Experiment 2. In other words, in Experiment 1, all participants received the question about the meaning of affix *kla*

first, followed by affix *ler*, and ending with affix *ran*. Opposed to this, the order in which participants were asked about the meaning of the affixes was randomised in Experiment 2. This difference could have had an influence on the way in which participants have answered the questions of the affix questionnaire because in Experiment 1, participants' answers showed that they often tended to get confused about the meaning category of *without* after answering the meaning category *opposite*. This was not the case for Experiment 2. Luckily, the results from the analysis on the difference between the testing phase answers showed that there was no significant difference between participants' performance between experiments. Therefore, possible repercussions of both design differences would only regard the categorisation participants to learner type.

In some cases, the answers of participants to the affix questionnaire pointed towards a mix between BLEND-learner and BUILD-learner behaviour. For example, some participants seemed unaware of the influence of the place of the affix for one or two affixes, but subsequently explicitly mentioned that influence for the last affix. This could suggest a developmental shift from the BLEND-strategy towards the BUILD-strategy that goes hand in hand with an increasing awareness about the sequential order rule. In section 2 (Hypothesis), the possibility was discussed that results pointing towards this developmental process could arise. Therefore, the additional remark was made about the phrasing of *learning strategies*, as they could be less like clear-cut strategies and more like a developmental process. Though, it remains unclear if this developmental shift indeed takes place for (some of the) participants, because the affix questionnaire answers do not indicate that all participants go through such a developmental shift.

5.6 Implications

Altmann (2012) argued that, in order to (successfully) infer and learn the meaning of novel compositional words, participants have to be aware of the internal structure of a compositional word whilst simultaneously understanding the function of each part of the structure. The findings of the present study coincide with this argument by showing that both BLEND-learners and BUILD-learners are aware of the compositionality (i.e., the internal structure) of the novel target words they learned during the experiment. Following Altmann (2012), this awareness leads to the fact that participants are able to detect the different parts of the novel compositional words, and subsequently are able to infer the meaning of those individual parts. This then results in the activation of the mental representation of the meanings of the individual parts. Thus, by deconstructing the novel compositional words into the stem and the derivational affix, participants of the present study were able to infer and activate the meaning of the individual parts, and eventually combine them together to infer the meaning of the entire compositional word (Altmann, 2012). Integrating the theory put forward by Martin (2016), the derivational affixes of the present study could be seen as the cues, as they are a representation of a certain piece of linguistic information (a certain meaning) that is subsequently linked to another cue. By integrating these cues (as proposed by Martin's Cue Integration Model) a certain linguistic representation is built, resulting in the creating of meaning that subsequently can be inferred (Martin, 2016). In other words, by integrating the derivational affix (a cue) with previously acquired stems (other cues), a certain linguistic representation is built (the novel compositional word), of which the meaning is subsequently inferred.

Additionally, the results of the present study are in favour of Altmann's argument (2012) in the sense that the degree to which humans are aware and understand the internal structure of compositional word influences the way in which they infer and learn its meaning. For example, BLEND-learners are to a lesser extent aware of the function of the derivational

affixes in the sense that they do not take the sequential order rule into account. In other words, they are not aware of the fact that affix *kla* means *young version* when it is a prefix and *opposite* when it is a suffix, but they infer either of those two meanings when they read affix *kla*, irrespectively of its place. Contrasting, BUILD-learners are to a greater extent aware of the function of the derivational affixes as they do take the sequential order rule into account. Thus, additional to knowing which two meanings the affix *kla* holds, BUILD-learners are aware that one meaning only holds when *kla* is a prefix and the other only holds when *kla* is a suffix. This perfectly corresponds with Martin (2020) as well, who argued that the meaning of compositional words is also constructed and computed by the regulations (or rules) that are used to make the specific structure. Thus, the specific knowledge that a participant has about the internal structure of the novel compositional words (such as the sequential order rule) has a significant influence on the process of how they infer and learn the corresponding meanings. This also has implications for the argument put forward by Jeffries (1998). He argued that a word's meaning is a reflection of some sort of general agreement amongst language users. The results from the present study show that individuals can infer novel word meaning in different manners, and thus that the reflection of a word's meaning can also differ between humans. This shows that the generalisability of the agreement about the meaning amongst language users is dependent on the way in which humans do (or do not) learn (abstract) rules in order to infer novel compositional word meaning.

The results of the present study also indicate that the knowledge about the internal structure and the function of the different parts of the novel compositional words that participants had previously acquired during the learning phase of the experiment is subsequently transferred to the unlearned novel compositional words of the testing phase. This coincides with what Hagoort (2013) described as Unification, which is one of the subdivisions of the MUC Model of language processing. Unification refers to the fact that humans have to

be able to retrieve previously acquired linguistic knowledge and subsequently use that to infer the meaning of new compositional structures. This is exactly what the participants did in the present experiment, as they transferred their knowledge from the learning phase in order to infer and learn the meaning of novel compositional words in the testing phase.

Moreover, the fact that participants were able to use the acquired knowledge from the learning phase to infer the meaning of the novel compositional words in the testing phase provides linguistic evidence for the Hierarchical Clustering Model that was proposed by Collins and Frank (2016). The model described that humans deduct and find structures that are subsequently clustered into rule sets. These have a facilitating role in the repeated use of the previously acquired knowledge in new situations, showing that the rule sets are latent (i.e., they can be used in other similar contexts). However, the Hierarchical Clustering Model did not specifically regard language. The results of the present study expand the Model's generalisability by showing that humans are able to apply similar rule sets in order to infer and learn novel word meaning.

5.7 Future Research

Martin (2016) argued that more empirically tested information on language processing is needed with regard to the combination of psycholinguistic and neurolinguistic language theories. The results from the present study provide significant psycholinguistic insights about language processing, and more specifically about how humans infer and learn novel compositional word meaning that is the result of derivational affixation. To further our understanding on this topic, the data from the present study will be used in a follow-up fMRI repetition suppression study on the same novel compositional words. By combining the present behavioural/linguistic study and the neurolinguistic fMRI study, and thus zooming in on the mental representations of meaning, the gap between the two fields will be bridged and the

neural code of word meaning that is generated almost instinctively will be examined in more detail.

Moreover, future research could examine into more detail if the aforementioned developmental shift from the BLEND-strategy to the BUILD-strategy indeed takes place for (some of the) participants to further our understanding about how participants infer and learn novel compositional word meaning.

6. Conclusion

The aim of the present study was to further our understanding of language processing by investigating into more detail how humans infer and learn novel compositional word meaning. It can be concluded that overall, humans are able to infer and learn novel compositional word meaning by transferring previous acquired knowledge to novel situations or contexts. This can be taken from the results of the two behavioural experiments, that showed that none of the participants adopted a flat, associative learning strategy. Furthermore, the results illustrated that humans are generally able to take the compositionality of compositional words into account in the process of inferring and learning the meaning of novel words, showing that they are able to learn (abstract) rules. Though, this process differs between humans with regard to whether they take the sequential order rule into account. As the results showed that BLEND-learners more often indicated order-incongruent novel compositional words to be meaningful, it can be stated that whether or not humans are aware of this sequential order rule has an influence on the exact way in which they infer and learn novel compositional word meaning.

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Appendix

Appendix A) Consent form

Toestemmingsformulier

Beschrijving van de taak

In deze studie gaat u een aantal taken uitvoeren waarbij u een aantal nieuwe woorden lezen en leren. Vervolgens zult u zelf de betekenis van nieuwe woorden moeten noteren, aan de hand van de informatie die u heeft opgedaan bij de eerste taak. Al uw gegevens worden beschermd volgens de Europese privacywetgeving.

Het onderzoek duurt ongeveer 60 minuten. U krijgt in ongeveer 7,5 euro betaald, op basis van een betalingstarief van 7.5 euro per uur. U kunt tijdens het onderzoek pauzes nemen als dat nodig is, maar houd er rekening mee dat de betaallink pas beschikbaar is aan het einde van het onderzoek. Houd er rekening mee dat u maximaal 2 uur de tijd kunt nemen om de studie af te ronden (studietijd limiet).

Waarschuwing: ons algoritme kan ongebruikelijk gedrag detecteren en zal uw deelname automatisch markeren. Bij ongewoon gedrag wordt uw deelname afgewezen en krijgt u geen vergoeding.

Risico's, voordelen en vertrouwelijkheid: hoewel u persoonlijk geen baat zult hebben bij dit onderzoek, hopen we dat de resultaten zullen bijdragen aan wetenschappelijke kennis over gedrag. Al uw reacties worden anoniem verzameld en verwerkt.

Vragen: Dit onderzoek wordt uitgevoerd onder begeleiding van Roshan Cools, hoogleraar aan het Donders Instituut, Radboud Universitair Medisch Centrum Nijmegen. Heeft u vragen over deze studie of over de betaling, neem dan contact op met j.roelofs@student.ru.nl

Door onderstaand bericht te ondertekenen:

Bevestigt u dat:

- Ik heb mijn deelname aan het experiment zorgvuldig overwogen.
- Ik doe mee uit eigen vrije wil.

Ik ben het er mee eens dat:

- Mijn gegevens anoniem worden verzameld en opgeslagen voor wetenschappelijke doeleinden.

Ik begrijp dat:

- Ik heb het recht om me op elk moment uit het experiment terug te trekken zonder een reden op te geven.
- Mijn privacy is beschermd volgens de Europese privacywet (AVG).
- Elke keer dat ik deelneem aan een nieuw experiment, mijn toestemming wordt gevraagd.

Ik heb bovenstaande informatie gelezen en ik geef toestemming.

Appendix B) Overview of Stimuli Materials for Experiment 1

Learning Phase						
Prefix KLA Young version						
N -> N		<i>Example</i>	<i>Stem translatie</i>	<i>Synonym</i>	<i>Synonym trans</i>	<i>Meaning</i>
		Klavrouw	Woman	Meisje	Girl	The young version of a vrouw (woman)
		Klavolwassene	Adult	Kind	Child	The young version of a volwassene (adult)
		Klahond	Dog	Puppy	Puppy	The young version of a hond (dog)
		Klakat	Cat	Kitten	Kitten	The young version of a kat (cat)
		Klaleeuw	Lion	Welp	Cub	The young version of a leeuw (lion)
Suffix KLA Opposite						
Adj -> Adj		<i>Example</i>	<i>Stem translatie</i>	<i>Synonym</i>	<i>Synonym trans</i>	<i>Meaning</i>
		Oudkla	Old	Jong	Young	The opposite of oud (old)
		Rijkkla	Rich	Arm	Poor	The opposite of rijk (rich)
		Alleskla	Everything	Niets	Nothing	The opposite of alles (everything)
		Donkerkla	Dark	Licht	Light	The opposite of donker (dark)
		Dagkla	Day	Nacht	Night	The opposite of dag (day)
Prefix RAN Without						
N -> Adj		<i>Example</i>	<i>Stem translatie</i>	<i>Synonym</i>	<i>Synonym trans</i>	<i>Meaning</i>
		Rangeluid	Sound	Stil	Quiet	Without geluid (sound)
		Raneten	Food	Hongerig	Hungry	Without eten (food)
		Ranreligie	Religion	Atheïstisch	Atheistic	Without religie (religion)
		Raninhoud	Contents	Leeg	Empty	Without inhoud (contents)
		Randrinken	Drinks	Dorstig	Thirsty	Without drinken (drinks)
Suffix RAN Strong version						
Adj -> Adj		<i>Example</i>	<i>Stem translatie</i>	<i>Synonym</i>	<i>Synonym trans</i>	<i>Meaning</i>
		Somsran	Sometimes	Zelden	Rarely	The strong version of soms (sometimes)
		Regelmatigran	Regularly	Vaak	Often	The strong version of regelmatig (regularly)
		Oudran	Old	Bejaard	Ancient	The strong version of oud (old)
		Warmran	Warm	Heet	Hot	The strong version of warm (hot)
		Grootran	Large	Enorm	Huge	The strong version of groot (large)
Prefix LER Person who engages with						
N -> N		<i>Example</i>	<i>Stem translatie</i>	<i>Synonym</i>	<i>Synonym trans</i>	<i>Meaning</i>
		Lerbrood	Bread	Bakker	Baker	Person who engages with brood (bread)
		Lertrein	Train	Conducteur	Train driver	Person who engages with trein (train)
		Lerboek	Book	Schrijver	Reader	Person who engages with boek (book)
		Lervliegtuig	Airplane	Piloot	Pilot	Person who engages with vliegtuig (airplane)
		Lerschool	School	Docent	Teacher	Person who engages with school (docent)
Suffix LER Color of						
N -> Adj		<i>Example</i>	<i>Stem translatie</i>	<i>Synonym</i>	<i>Synonym trans</i>	<i>Meaning</i>
		Bloedler	Blood	Rood	Red	The color of bloed (blood)
		Luchtler	Sky	Blauw	Blue	The color of the lucht (sky)
		Pupiller	Pupil	Zwart	Black	The color of a pupil (pupil)
		Sneeuwler	Snow	Wit	White	The color of sneeuw (snow)
		Houtler	Wood	Bruin	Brown	The color of hout (wood)

Testing Phase				
Order-Incongruent Condition				
Prefix KLA		Young version		
		Example	Synonym	Meaning
		Klakort	?	The young version of kort (short)
		Klaheet	?	The young version of heet (hot)
		Klalinks	?	The young version of links (left)
		Klaleeg	?	The young version of leeg (empty)
		Klahoog	?	The young version of hoog (high)
Suffix KLA		Opposite		
		Example	Synonym	Meaning
		Paardkla	?	The opposite of paard (horse)
		Kipkla	?	The opposite of kip (chicken)
		Koekla	?	The opposite of koe (cow)
		Schaapkla	?	The opposite of schaap (sheep)
		Menskla	?	The opposite of mens (human)
Prefix RAN		Without		
		Example	Synonym	Meaning
		Rangoed	?	Without goed (good)
		Ranstom	?	Without stom (stupid)
		Rankoel	?	Without koel (cool)
		Ranklein	?	Without klein (small)
		Ranlastig	?	Without lastig (difficult)
Suffix RAN		Strong version		
		Example	Synonym	Meaning
		Haarran	?	The strong version of haar (hair)
		Zichtran	?	The strong version of zicht (sight)
		Klerenran	?	The strong version of kleren (clothes)
		Kostenran	?	The strong version of kosten (expenses)
		Energieran	?	The strong version of energie (energy)
Prefix LER		Person who engages with		
		Example	Synonym	Meaning
		Lerbanaan	?	Person who engages in banaan (banana)
		Lergras	?	Person who engages in gras (grass)
		Lerolifant	?	Person who engages in olifant (elephant)
		Leraubergine	?	Person who engages in aubergine (eggplant)
		Lermandarijn	?	Person who engages in mandarijn (tangerine)
Suffix LER		Color of		
		Example	Synonym	Meaning
		Keukenler	?	The color of keuken (kitchen)
		Heelaller	?	The color of heelal (space)
		Toneeller	?	The color of toneel (theatre)
		Sportler	?	The color of sport (sports)
		Liedler	?	The color of lied (song)

Testing Phase					
Mismatch Condition					
Prefix KLA	Young version				
	<i>Example</i>	<i>Synonym</i>	<i>Meaning (+ prefix)</i>		<i>Meaning (+ suffix)</i>
	Klaenergie	?	The young version of energie (energy)		The opposite of energie (energy)
	Klakosten	?	The young version of kosten (expenses)		The opposite of kosten (expenses)
	Klakeuken	?	The young version of keuken (kitchen)		The opposite of keuken (kitchen)
	Klatoneel	?	The young version of toneel (theatre)		The opposite of toneel (theatre)
	Klalied	?	The young version of lied (song)		The opposite of lied (song)
Suffix KLA	Opposite of				
	<i>Example</i>	<i>Synonym</i>	<i>Meaning (+ suffix)</i>		<i>Meaning (+ prefix)</i>
	Graskla	?	The opposite of gras (grass)		The young version of gras (grass)
	Auberginekla	?	The opposite of aubergine (eggplant)		The young version of aubergine (eggplant)
	Mandarijnkla	?	The opposite of mandarijn (tangerine)		The young version of mandarijn (tangerine)
	Haarkla	?	The opposite of haar (hair)		The young version of haar (hair)
	Klerenkla	?	The opposite of kleren (clothes)		The young version of kleren (clothes)
Prefix RAN	Without				
	<i>Example</i>	<i>Synonym</i>	<i>Meaning (+ prefix)</i>		<i>Meaning (+ suffix)</i>
	Ranmens	?	Without mens (human)		The strong version of mens (human)
	Ranlinks	?	Without links (left)		The strong version of links (left)
	Ranolifant	?	Without olifant (elephant)		The strong version of olifant (elephant)
	Ranheelal	?	Without heelal (space)		The strong version of heelal (space)
	Ransport	?	Without sport (sports)		The strong version of sport (sports)
Suffix RAN	Strong version				
	<i>Example</i>	<i>Synonym</i>	<i>Meaning (+ suffix)</i>		<i>Meaning (+ prefix)</i>
	Koeran	?	The strong version of koe (cow)		Without koe (cow)
	Schaapran	?	The strong version of schaap (sheep)		Without schaap (sheep)
	Ranpaard	?	The strong version of paard (horse)		Without paard (horse)
	Kipran	?	The strong version of kip (chicken)		Without kip (chicken)
	Banaanran	?	The strong version of banaan (banana)		Without banaan (banana)
Prefix LER	Person who engages with				
	<i>Example</i>	<i>Synonym</i>	<i>Meaning (+ prefix)</i>		<i>Meaning (+ suffix)</i>
	Lerzicht	?	Person who engages in zicht (sight)		The color of zicht (sight)
	Lerhoog	?	Person who engages in hoog (high)		The color of hoog (high)
	Lerleeg	?	Person who engages in leeg (empty)		The color of leeg (empty)
	Lerlastig	?	Person who lastig (difficult)		The color of lastig (difficult)
	Lergoed	?	Person who engages in goed (good)		The color of goed (good)
Suffix LER	Color of				
	<i>Example</i>	<i>Synonym</i>	<i>Meaning (+ suffix)</i>		<i>Meaning (+ prefix)</i>
	Koeller	?	The color of koel (cool)		Person who engages in koel (cool)
	Kleinler	?	The color of klein (small)		Person who engages in klein (small)
	Stomler	?	The color of stom (stupid)		Person who engages in stom (stupid)
	Kortler	?	The color of kort (short)		Person who engages in kort (short)
	Heetler	?	The color of heet (hot)		Person who engages in heet (hot)

Appendix C) Overview of Stimuli Materials for Experiment 2

Learning Phase					
Prefix KLA Young version					
N -> N		<i>Example</i>	<i>Stem translation</i>	<i>Synonym</i>	<i>Synonym translation</i>
		Klavrouw	Woman	Meisje	Girl
		Klavolwasser	Adult	Kind	Child
		Klahond	Dog	Puppy	Puppy
		Klakat	Cat	Kitten	Kitten
		Klaleeuw	Lion	Welp	Cub
Suffix KLA Opposite					
Adj -> Adj		<i>Example</i>	<i>Stem translation</i>	<i>Synonym</i>	<i>Synonym translation</i>
		Oudkla	Old	Jong	Young
		Rijkkla	Rich	Arm	Poor
		Alleskla	Everything	Niets	Nothing
		Donkerkla	Dark	Licht	Light
		Dagkla	Day	Nacht	Night
Prefix RAN Without					
N -> Adj		<i>Example</i>	<i>Stem translation</i>	<i>Synonym</i>	<i>Synonym translation</i>
		Rangeluid	Sound	Stil	Quiet
		Raneten	Food	Hongerig	Hungry
		Rankleren	Clothes	Naakt	Naked
		Ranleider	Leader	Anarchistisch	Anarchic
		Randrinken	Drinks	Dorstig	Thirsty
Suffix RAN Color of					
N -> Adj		<i>Example</i>	<i>Stem translation</i>	<i>Synonym</i>	<i>Synonym translation</i>
		Bloedran	Blood	Rood	Red
		Luchtran	Sky	Blauw	Blue
		Grasran	Grass	Groen	Green
		Sneeuwran	Snow	Wit	White
		Zonran	Sun	Geel	Yellow
Prefix LER Person who engages in					
N -> N		<i>Example</i>	<i>Stem translation</i>	<i>Synonym</i>	<i>Synonym translation</i>
		Lermuziek	Music	Artiest	Artist
		Leradvies	Advice	Raadgever	Counselor
		Lerboek	Book	Lezer	Reader
		Lervliegtuig	Airplane	Piloot	Pilot
		Lerschool	School	Docent	Teacher
Suffix LER Strong version					
Adj -> Adj		<i>Example</i>	<i>Stem translation</i>	<i>Synonym</i>	<i>Synonym translation</i>
		Somsler	Sometimes	Zelden	Rarely
		Stomler	Stupid	Verschrikkelijk	Horrible
		Oudler	Old	Antiek	Ancient
		Koeller	Cool	Koud	Cold
		Grootler	Large	Immens	Huge

Testing Phase					
Order-Congruent Condition					
Prefix KLA		Young version			
N -> N		<i>Example</i>	<i>Stem translation</i>	<i>Synonym</i>	<i>Synonym translation</i>
		Klapaard	Horse	Veulen	Foal
		Klakip	Chicken	Kuiken	Chick
		Klakoe	Cow	Kalf	Calf
		Klaschaap	Sheep	Lam	Lamb
		Klamens	Human	Baby	Baby
Suffix KLA		Opposite			
Adj -> Adj		<i>Example</i>	<i>Stem translation</i>	<i>Synonym</i>	<i>Synonym translation</i>
		Kortkla	Short	Lang	Long
		Heetkla	Hot	Koud	Cold
		Linkskla	Left	Rechts	Right
		Volkla	Full	Leeg	Empty
		Hoogkla	High	Laag	Low
Prefix RAN		Without			
N -> Adj		<i>Example</i>	<i>Stem translation</i>	<i>Synonym</i>	<i>Synonym translation</i>
		Ranhaar	Hair	Kaal	Bald
		Ranzicht	Sight	Blind	Blind
		Ranreligie	Religion	Atheïstisch	Atheistic
		Rankosten	Expenses	Gratis	Free
		Ranenergie	Energy	Moe	Tired
Suffix RAN		Color of			
N -> Adj		<i>Example</i>	<i>Stem translation</i>	<i>Synonym</i>	<i>Synonym translation</i>
		Banaanran	Banana	Geel	Yellow
		Pupilran	Pupil	Zwart	Black
		Olifantran	Elephant	Grijs	Grey
		Aubergineran	Eggplant	Paars	Purple
		Mandarijnran	Tangerine	Oranje	Orange
Prefix LER		Person who engages in			
N -> N		<i>Example</i>	<i>Stem translation</i>	<i>Synonym</i>	<i>Synonym translation</i>
		Leikeuken	Kitchen	Kok	Chef
		Leionderzoek	Study	Wetenschapper	Researcher
		Leitoneel	Theatre	Acteur	Actor
		Leitrein	Train	Conducteur	Train driver
		Leiles	Lesson	Leerling	Student
Suffix LER		Strong version			
Adj -> Adj		<i>Example</i>	<i>Stem translation</i>	<i>Synonym</i>	<i>Synonym translation</i>
		Goedler	Good	Geweldig	Amazing
		Primaler	Fine	Uitstekend	Excellent
		Warmler	Warm	Heet	Hot
		Kleinler	Small	Miniem	Tiny
		Lastigler	Difficult	Moeilijk	Difficult

Testing Phase				
Order-Incongruent Condition				
Prefix KLA		Young version		
N -> N		<i>Example</i>	<i>Synonym</i>	<i>Synonym translation</i>
		Klakort	?	The young version of kort
		Klaheet	?	The young version of heet
		Klalinks	?	The young version of links
		Klavol	?	The young version of vol
		Klahoog	?	The young version of hoog
Suffix KLA		Opposite		
Adj -> Adj		<i>Example</i>	<i>Synonym</i>	<i>Synonym translation</i>
		Paardkla	?	The opposite of paard
		Kipkla	?	The opposite of kip
		Koekla	?	The opposite of koe
		Schaapkla	?	The opposite of schaaap
		Menskla	?	The opposite of mens
Prefix RAN		Without		
N -> Adj		<i>Example</i>	<i>Synonym</i>	<i>Synonym translation</i>
		Ranbanaan	?	Without banaan
		Ranpupil	?	Without pupil
		Ranolifant	?	Without olifant
		Ranaubergine	?	Without aubergine
		Ranmandarijn	?	Without mandarijn
Suffix RAN		Color of		
N -> Adj		<i>Example</i>	<i>Synonym</i>	<i>Synonym translation</i>
		Haarran	?	Color of haar
		Zichtran	?	Color of zicht
		Religieran	?	Color of religie
		Kostenran	?	Color of kosten
		Energieran	?	Color of energie
Prefix LER		Person who engages in		
N -> N		<i>Example</i>	<i>Synonym</i>	<i>Synonym translation</i>
		Lergoed	?	Person who engages in goed
		Lerprima	?	Person who engages in prima
		Lerwarm	?	Person who engages in warm
		Lerklein	?	Person who engages in klein
		Lerlastig	?	Person who engages in lastig
Suffix LER		Strong version		
Adj -> Adj		<i>Example</i>	<i>Synonym</i>	<i>Synonym translation</i>
		Keukenler	?	Strong version of keuken
		Onderzoekler	?	Strong version of onderzoek
		Toneeller	?	Strong version of toneel
		Treinler	?	Strong version of trein
		Lesler	?	Strong version of les

Testing Phase					
Mismatch Condition					
Prefix KLA		Young version			
N -> N		<i>Example</i>	<i>Synonym</i>	<i>Meaning (+ prefix)</i>	<i>Meaning (+ suffix)</i>
		Klakeuken	?	The young version of keuken	The opposite of keuken
		Klales	?	The young version of les	The opposite of les
Suffix KLA		Opposite			
Adj -> Adj		<i>Example</i>	<i>Synonym</i>	<i>Meaning (+ suffix)</i>	<i>Meaning (+ prefix)</i>
		Toneelkla	?	The opposite of toneel	The young version of toneel
		Pupilkla	?	The opposite of pupil	The young version of pupil
		Onderzoekk	?	The opposite of onderzoek	The young version of onderzoek
Prefix RAN		Without			
N -> Adj		<i>Example</i>	<i>Synonym</i>	<i>Meaning (+ prefix)</i>	<i>Meaning (+ suffix)</i>
		Rantrein	?	Without trein	Color of trein
		Ranlinks	?	Without links	Color of links
Suffix RAN		Color of			
N -> Adj		<i>Example</i>	<i>Synonym</i>	<i>Meaning (+ suffix)</i>	<i>Meaning (+ prefix)</i>
		Volran	?	Color of vol	Without vol
		Kleinran	?	Color of klein	Without klein
		Lastigran	?	Color of lastig	Without lastig
Prefix LER		Person who engages in			
N -> N		<i>Example</i>	<i>Synonym</i>	<i>Meaning (+ prefix)</i>	<i>Meaning (+ suffix)</i>
		Lerenergie	?	Person who engages in energie	Strong version of energie
		Leraubergine	?	Person who engages in aubergine	Strong version of aubergine
		Lermandarij	?	Person who engages in mandarijn	Strong version of mandarijn
Suffix LER		Strong version			
Adj -> Adj		<i>Example</i>	<i>Synonym</i>	<i>Meaning (+ suffix)</i>	<i>Meaning (+ prefix)</i>
		Mensler	?	Strong version of mens	Person who engages in mens
		Olifantler	?	Strong version of olifant	Person who engages in olifant
Prefix SEN		[no meaning]			
		<i>Example</i>	<i>Synonym</i>	<i>Meaning (+ suffix)</i>	<i>Meaning (+ prefix)</i>
		Senbanaan	?	-	-
		Senreligie	?	-	-
		Senkosten	?	-	-
		Senhaar	?	-	-
		Senkort	?	-	-
		Senheet	?	-	-
		Senpaard	?	-	-
Suffix SEN		[no meaning]			
		<i>Example</i>	<i>Synonym</i>	<i>Meaning (+ suffix)</i>	<i>Meaning (+ prefix)</i>
		Warmsen	?	-	-
		Hoogsen	?	-	-
		Primasen	?	-	-
		Goedsen	?	-	-
		Kipsen	?	-	-
		Koesen	?	-	-
		Schaapsen	?	-	-
		Zichtsen	?	-	-

Appendix D) Instruction participants

Ergens op de wereld is een nieuwe samenleving ontdekt die een vreemde taal spreekt. Om te kunnen communiceren met deze samenleving is het noodzakelijk om hun taal te begrijpen en leren. Het onderzoeksteam weet zich tot nu toe echter geen raad met de vreemde taal die de samenleving spreekt. Wel heeft het team opgemerkt dat de taal veel op het Nederlands lijkt. Daarom ben jij, als Nederlandse taalspreker, gevraagd het onderzoeksteam te versterken. Je gaat zo meteen beginnen aan de uitdaging om de vreemde taak van de ontdekte samenleving te ontcijferen. Lukt het jou wel om de vreemde taal te begrijpen?

Het onderzoeksteam heeft een aantal woorden opgeschreven waarvan ze de betekenis al wel achterhaald hebben. Je begint met de *onderzoeksfase*, waarin je de woorden met bijbehorende betekenissen zult gaan lezen. Vervolgens lees je een voorbeeldzin¹² waar het desbetreffende woord in voorkomt. Hier volgt een voorbeeld:

Kladicht = Open. Voorbeeld: Om 9 uur 's ochtends gaan de deuren van de supermarkt kladicht.

Zoals je ziet in het voorbeeld, staat het nieuwe woord uit de vreemde taal aan de linkerkant van het =teken. De betekenis van het woord staat aan de rechterkant van het =teken. Daarna volgt er een voorbeeldzin. Neem je tijd om alle nieuwe woorden rustig te lezen. Elk woord zal maximaal 15 seconden op het scherm staan. Daarna ga je automatisch door naar het volgende woord. Wanneer je al eerder denkt dat je de betekenis van een nieuw woord doorhebt, druk je op 'volgende', waarna er een nieuw woord op je scherm verschijnt.

Je krijgt zo meteen alle nieuwe woorden een keer te zien, gevolgd door een vragenlijst waarbij je gevraagd wordt om de juiste betekenis van de woorden aan te geven. Vervolgens zal je alle nieuwe woorden nogmaals zien. Dit proces wordt een aantal keer herhaald. Het is niet nodig om de nieuwe woorden in één keer allemaal te onthouden. Door op de onderstaande knip te klikken, begin je met het lezen van de nieuwe woorden.

¹² Only Experiment 2 included the example sentences in the learning phase, as part of ensuring a deeper encoding of the meaning.

Appendix E) Experiment 2 Learning Phase Example Sentences

De klavrouw vierde vandaag haar zevende verjaardag.
De klavolwassene gleed van de glijbaan in de speeltuin.
De golden retriever is bevallen van vier klahonden.
De grote poes is acht jaar oud, de kleine poes is een klakat.
Er is net een klaleeuw geboren in de dierentuin.

Het meisje is net drie maanden oud, ze is erg oudkla.
De man was te rijkkla om zijn boodschappen te betalen.
Het is veel te donker hier, ik zie alleskla!
De lamp zorgde ervoor dat de kamer donkerkla werd.
Wanneer het dagkla is, zie je de maan en de sterren.

De kamer was compleet rangeluid, je kon er een speld horen vallen.
Ik heb al vier uur niets gegeten, ik ben raneten.
In sommige culturen is rankleren zijn een taboe.
Wanneer een land geen duidelijke regeringsvorm heeft, is het land ranleider.
Ik ben mijn drinkfles vergeten dus ik ben erg randrinken.

Bloedran rozen staan vaak symbolisch voor de liefde.
Het gezin ging luchtran ballonnen op omdat ze in verwachting zijn van een jongen.
In de lente worden alle bomen weer grasran.
Mijn huid is zo sneeuwran: ik lijk wel een spook!
Als bananen rijp zijn, zijn ze zonran van kleur.

De lermuziek heeft een fantastisch optreden neergezet met zijn band.
Met de raad van de leradvies kan ik mijn probleem oplossen.
Zij is een echte lerboek: ze verslindt het ene boek na het andere.
De lervliegtuig wenste iedereen een prettige vlucht vanuit de cockpit.
Haar favoriete lerschool is meneer Aarts van Engels.

Dit gebeurt bijna nooit, het is erg somsler.
Presenteren haat ik enorm, ik vind het stomler.
Dit tafeltje is wel honderd jaar oud, het is oudler.
Morgen wordt het -10 graden Celsius, dat is koeller.
De afstand tussen twee sterren in het heelal is grootler.

Appendix F) Answer possibilities on the learning phase multiple-choice questions

Weik van de onderstaande woorden betekent **meisje**?	klavrouw	randrinken	ranvrouw	kladrinken	ranvrouw	klavrouw	kladrinken	randrinken
Weik van de onderstaande woorden betekent **puppy**?	klahond	klasoms	klahond	klasoms	klahond	klavrouw	kladrinken	randrinken
Weik van de onderstaande woorden betekent **kitten**?	klakat	klagroot	klakat	klagroot	klakat	grootler	somsler	klasoms
Weik van de onderstaande woorden betekent **kind**?	klavolwasser	klasneeuw	volwassener	klasneeuw	volwassener	klavolwasser	klasneeuw	volwasseneran
Weik van de onderstaande woorden betekent **welp**?	klaleeuw	klageluid	leeuwrans	klageluid	leeuwrans	klaleeuw	klageluid	leeuwrans
Weik van de onderstaande woorden betekent **jong**?	oudkla	vliegtuigkla	leroud	vliegtuigkla	leroud	leroud	vliegtuigkla	oudkla
Weik van de onderstaande woorden betekent **nacht**?	donkerkla	boekkla	lerdonker	boekkla	lerdonker	lerboek	boekkla	lerdonker
Weik van de onderstaande woorden betekent **arm**?	dagkla	etenkla	dagran	etenkla	dagran	zonran	raneten	dagkla
Weik van de onderstaande woorden betekent **niets**?	alleskla	stomkla	allesler	stomkla	allesler	advieskla	stomler	allesler
Weik van de onderstaande woorden betekent **raadgever**?	leradvies	leroud	advieskla	leroud	advieskla	klavliegtuig	leroud	leradvies
Weik van de onderstaande woorden betekent **piloot**?	lervliegtuig	klavrouw	klavliegtuig	lervrouw	klavliegtuig	klavliegtuig	lervliegtuig	lervrouw
Weik van de onderstaande woorden betekent **artiest**?	lermuziek	rijkkla	muziekkla	lerrijk	muziekkla	lerrijk	rijkkla	lermuziek
Weik van de onderstaande woorden betekent **docent**?	lerschool	luchtran	schoolran	lerlucht	luchtran	lerlucht	schoolran	lerschool
Weik van de onderstaande woorden betekent **lezer**?	lerboek	grasran	boekran	lergras	boekran	boekran	grasran	lerboek
Weik van de onderstaande woorden betekent **zelden**?	somsler	ranleider	ransoms	leiderler	somsler	ranleider	ransoms	leiderler
Weik van de onderstaande woorden betekent **immens**?	grootler	klavolwasser	klavolwasser	volwassener	klavolwasser	grootler	volwassener	klavolwasser
Weik van de onderstaande woorden betekent **antiek**?	oudler	rankleren	ranoud	klarenler	rankleren	oudler	klarenler	ranoud
Weik van de onderstaande woorden betekent **verschrikkelijk**?	stomler	bloedran	stomran	bloedler	stomler	bloedran	stomran	bloedler
Weik van de onderstaande woorden betekent **koud**?	koeller	alleskla	koelkla	allesler	alleskla	allesler	koeller	koelkla
Weik van de onderstaande woorden betekent **stil**?	rangeluid	lerschool	lergeluid	ranschool	rangeluid	lergeluid	lerschool	rangeluid
Weik van de onderstaande woorden betekent **anarchistisch**?	ranleider	klakat	klaleider	rankat	klakat	rankat	klaleider	ranleider
Weik van de onderstaande woorden betekent **hongerig**?	raneten	oudler	etenler	ranoud	oudler	etenler	raneten	ranoud
Weik van de onderstaande woorden betekent **naakt**?	rankleren	lermuziek	lerkleren	ranmuziek	rankleren	lerkleren	lermuziek	ranmuziek
Weik van de onderstaande woorden betekent **dorstig**?	randrinken	leradvies	lerdrinken	ranadvies	randrinken	ranadvies	lerdrinken	randrinken
Weik van de onderstaande woorden betekent **wit**?	sneeuwrans	klaleeuw	klasneeuw	leeuwrans	klasneeuw	klaleeuw	sneeuwrans	leeuwrans
Weik van de onderstaande woorden betekent **geel**?	zonran	dagkla	zonkla	dagran	zonran	dagkla	zonkla	dagran
Weik van de onderstaande woorden betekent **rood**?	bloedran	donkerkla	bloedkla	donkerran	bloedkla	bloedran	donkerkla	donkerran
Weik van de onderstaande woorden betekent **blauw**?	luchtran	klahond	klalucht	hondran	klahond	hondran	klalucht	klalucht
Weik van de onderstaande woorden betekent **groen**?	grasran	koeller	grasler	koelran	grasran	koeller	grasler	koelran