Learning abstract words: Role of valence in linguistic context

LEARNING ABSTRACT WORDS: ROLE OF VALENCE IN LINGUISTIC CONTEXT

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Lay Abstract

"The girl walked her plurk down the street." Did you think of a dog? Adults are constantly learning new words by inferring the meaning through context. By making small changes to word and sentence stimuli we can study how semantic properties such as emotion (positive, neutral, or negative) and concreteness (e.g., "lamp" is a physical object that can be touched, making it high in concreteness, while "hope" cannot be touched and is therefore low in concreteness, or abstract) interact. In the current study, we manipulate contexts to vary in emotionality and words to vary in concreteness. Participants read short passages containing new words and were given a surprise test after that measured how well they learned the emotionality, forms, and meanings of the new words. This study presents new insight for theories of how new words are learned and stored in the brain and have implications for language learning materials.

Abstract

This study investigates the role of emotional linguistic input in learning novel words with abstract and concrete denotations. It is widely accepted that concrete concepts are processed more easily than abstract ones. Several theories of vocabulary acquisition additionally propose that learning of concrete concepts puts greater weight on sensorimotor information while abstract concepts put greater weight on emotional information. In this study, proficient adult speakers of English read novel words denoting concrete and abstract concepts (e.g., *boat* vs *religion*) embedded in informative passages with different emotional valence (positive, neutral and negative). After five exposures to each novel word in an emotionally consistent context, participants were tested on orthographic and semantic vocabulary learning and provided valence judgments of these novel words. Readers successfully learned orthographic form and meaning of novel words, with a concreteness advantage seen in both tasks measuring semantic learning. Critically, valence of linguistic contexts was more influential for novel words with concrete denotations. In line with previous reports, the transfer of context emotionality to novel words (i.e., semantic prosody) took place in concrete stimuli and not abstract stimuli, even though they were both embedded in emotional contexts. An equal advantage was seen for semantic learning of novel words with both concrete and abstract denotations seen in positive contexts. These findings provide counter-evidence to theories advocating greater reliance of abstract concept learning on emotional information.

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Introduction

Cognitive scientists have emphasized the importance of sensorimotor information (i.e., bodily states) in grounding the meanings of concepts in the brain (e.g., Barsalou, 1999; Barsalou, Barbey, Simmons, & Wilson, 2003; Zwaan, 2004). Under the label of embodied cognition, several theories that vary in the level of embodiment (e.g., Vigliocco et al., 2004; Mahon & Caramazza, 2008; Gallese & Lakoff, 2005) have been proposed that describe the role of sensorimotor input on learning, and how language is understood due to the elicitation of the sensorimotor experience related to the referent of a word. In fact, several studies have demonstrated that there are similar brain activation patterns for body movements and viewing of words that describe body movements (Hauk, Johnsrude, & Pulvermüller, 2004; Pulvermüller, Hauk, Nikulin, & Ilmoniemi, 2005). However, concepts low in concreteness (e.g., words denoting abstract concepts such as hope, chance, and freedom) challenge embodied theories of cognition: When a concept has no tangible, real world referent, how is it represented and processed? What information is activated when hearing or reading an abstract word? Several accounts have been proposed to build on embodied theories of cognition to include abstract concepts, such as the Affective Embodiment Account (Kousta et al., 2009), which emphasizes the role of affect, or emotion, in abstract word learning. The aim of the current thesis is to gain further understanding of how concreteness and affect interact by employing a word learning paradigm and observing learning of abstract concepts in linguistic contexts that vary in affect.

As mentioned above, embodied theories of cognition can be divided into groups varying in levels of embodiment: 1) Strong embodiment (e.g., Gallese & Lakoff, 2005; Glenberg & Kaschak, 2003; Zwaan, 2004) which propose that semantic content is completely represented in sensorimotor regions via simulation; 2) Weak embodiment (e.g., Barsalou, 1999; Farah &

McClelland, 1991; Pulvermuller, 1999; Vigliocco, Vinson, Lewis, & Garrett, 2004) which propose a partial dependence on sensorimotor regions, and 3) Secondary embodiment (e.g., Mahon & Caramazza, 2008; Patterson et al., 2007; Rogers et al., 2004) which proposes that while semantic content is independent from sensorimotor regions, it is associated to brain regions that represent them (see Meteyard, Cuadrado, Bahrami & Vigliocco, 2012 for full overview of all levels).

On this continuum of embodiment, which level can best account for abstract word processing? For strong embodiment, Lakoff and Johnson (1999) suggested that abstract concepts are represented through “conceptual metaphor”: Concrete concepts provide grounding for abstract concepts through metaphorical extension. For example, the abstract concept of “understanding” can be learned through an expression such as “to grasp an idea.” Indeed, Boulenger et al. (2009) found that idiomatic expressions such as “to grasp an idea” activate motor areas (although see Aziz-Zadeh, Wilson, Rizzolatti, & Iacoboni, 2006 for conflicting findings). Theories falling under secondary embodiment have also found conflicting evidence of amodal representation. Using electroencephalography (EEG), Dalla Volta et al. (2014) compared processing of concrete and abstract words, finding that only concrete words had early sensorimotor activation. However, Dreyer et al. (2015) found that damage to the supplementary motor cortex caused difficulties in recognizing abstract emotional words. Vukovic et al. (2017) found, using repetitive transcranial magnetic stimulation (rTMS), that stimulating the motor cortex caused difficulties with processing action-related words, but not abstract words. Evidently, neuroimaging evidence has been inconclusive on the role that sensorimotor areas have on knowledge representation, and the degree to which sensorimotor systems interact with processing of concrete or abstract words. Theories falling under weak embodiment provide both theoretical accounts and experimental evidence for representation of abstract knowledge. Vigliocco et al. (2009) suggest that two sources of information are utilized, regardless of concreteness of the word: 1) experiential, which includes sensorimotor but also affective information, and 2) linguistic, which is the associations learned through co-occurrences of words in texts. Kousta et al. (2009) provide evidence for this account in a study showing that abstract words are learned using affective information, and furthermore, abstract words with increased affective associations are learned earlier. More recently, Kousta, Vigliocco, Vinson, Andrews & Del Campo (2011) proposed that abstract concepts put a greater weight on affective information while concrete concepts on sensorimotor information. This final account of weak embodiment is the theory of focus in the current thesis.

The study presented below uses a word learning paradigm to investigate whether affective information in the linguistic context surrounding a novel word can bootstrap word learning. The current study can provide experimental evidence for weak embodiment: Can novel words with abstract denotations be learned entirely through a linguistic context, and furthermore, does affective information in this context contribute to learning? Previous studies have found that linguistic context, particularly linguistic context that has a positive affect, can facilitate faster response times, and improved recognition and learning (Kuperman, Estes, Brysbaert, & Warriner, 2014; Snefjella & Kuperman, 2016; Snefjella, Lana, & Kuperman, 2020). Additionally, there have been an increasing number of developmental studies examining learning of abstract words in children (e.g., Ponari et al., 2017, Vigliocco et al., 2018; see the present study below for overview). However, it has yet to be found how affect of linguistic context can influence learning of abstract words for adult speakers of a language, which is addressed in the current study.

It is important to note well established semantic properties that provide advantages in lexical processing and memory such as concreteness (e.g., Paivio, 1991; Schwanenflugel, 1991; Salsbury, Crossley, & McNamara, 2011) and affect (also referred to as emotionality, or valence, e.g., Sheikh & Titone, 2013; Pexman, Hargreaves, Siakaluk, Bodner, & Pope, 2008). A lexical advantage for various semantic properties can be attributed to the Semantic Richness Effect (Balota et al., 1991), which claims that the more associations a word has (e.g., semantic neighbours, semantic features) the more quickly and accurately it is processed. Theories of semantic representation disagree on whether abstract concepts lack semantic richness and rely solely on linguistic associations (Paivio, 2010; Plaut & Shallice, 1993), or have increased semantic associations that are grounded in bodily experience (see above; Barsalou et al., 2008). Similarly, the Lexical Quality Hypothesis (Perfetti & Hart, 2002; Perfetti, 2007) proposes that the emotional and sensorimotor information found in linguistic contexts influences semantic representation.

In addition to the individual affect (i.e., emotionality) of words, the role of the surrounding linguistic context that a word occurs in has been explored. Using large corpora of texts, Snefjella and Kuperman (2016) investigated the role of concreteness and valence of the linguistic context that a word occurs in on response times in lexical tasks, finding that words co-occur with words of similar valence and that words tend to absorb their surrounding valence. Snefjella et al. (2020) experimentally examined novel word learning in linguistic contexts, finding that novel words learned through contexts with positive affect show advantages in post-tests measuring semantic and orthographic learning. The current study builds on Snefjella et al. (2020) to experimentally examine whether concreteness and valence can interact and influence attention and memory for novel words varying in concreteness.

Learning concrete and abstract novel words in emotional contexts: Evidence from incidental vocabulary learning

How people learn new words and what factors present a challenge or a boost to novel word learning are questions that have been at the forefront of psycholinguistics for decades (e.g., de Vos, Schriefers, Nivard, & Lemhöfer, 2018; Wasik, Hindman & Snell, 2016). The present study addresses an interaction of two factors that have been repeatedly deemed relevant for vocabulary acquisition – emotional valence and concreteness/abstractness of words to be learned as well as their contexts. We briefly review the literature discussing this interaction and present the logic and predictions of the current study.

Conceptual representations vary along the dimension of concreteness – abstractness. Concrete words have clear referents to material objects (e.g., *brick*) while abstract words (e.g., *temptation*) do not have tangible referents and can represent a mental state, a condition, or a situation (Borghi & Binkofski, 2014). Words rated as more concrete show a well-established cognitive advantage in word learning, memory, and recognition, as demonstrated by methodologies such as lexical decision, word naming tasks, memory recognition tasks and others (Ellis & Beaton, 1993; Paivio, 1991; Salsbury, Crossley, & McNamara, 2011). Influential interpretations of this concreteness advantage were given, among others, by the Dual Coding Theory (Paivio, 1986), and the Context Availability Model (Schwanenflugel, 1991; Schwanenflugel & Shoben, 1983). The Dual Coding Theory explains the processing advantage of concrete concepts as resulting from access to more information from multiple systems. Concrete words are represented in two distinct systems, verbal and imagistic, while abstract concepts are represented primarily or exclusively in the verbal system. Alternatively, the Context

Availability Model by Schwanenflugel and colleagues argues for a single system where concrete words have access to more previous semantic knowledge and have stronger associations to sentence context compared to abstract words. It predicts that if concrete and abstract words were presented in isolation, the concreteness effect would disappear. In a later development, the Extended Dual Coding Hypothesis (Holcomb, Kounios, Anderson & West, 1999) has integrated some premises of both previous theories, arguing and showing empirical support for the notion that the concreteness advantage can be attributed to connections that concrete concepts have in the verbal system and the imagery system, and also to the greater diversity of verbal contexts for concrete words.

A somewhat different interpretation of the concreteness advantage comes from embodied theories of cognition, which propose that knowledge of concepts is grounded in “bodily states, modal simulations, and situation action” (e.g., Barsalou, 1999; Barsalou, Barbey, Simmons, & Wilson, 2003). Embodied theories argue that processing semantic information activates the same neural systems that are activated during perception and action (Barsalou, 1999; Gibbs, 2006; Decety & Grezes, 2006). This activation is proposed as the reason for the concreteness effect, in which concrete words have an advantage due to knowledge gained from bodily experiences while more abstract words do not rely on such knowledge.

In the last decade, proponents of embodied cognition introduced an account that links the dimension of concreteness with affective dimensions to explain learning mechanisms for words and concepts (e.g., Barsalou, 2009; Vigliocco, Meteyard, Andrews & Kousta, 2009; Wilson-Mendanhall, Barrett, Simmons, & Barsalou, 2011). Thus, Barsalou (2003, 2009) proposes the Perceptual Symbol Systems framework which highlights the role simulation of situated knowledge, including emotional experience and knowledge, as being crucial to the processing and representation of abstract words. Furthermore, Wilson-Mendenhall et al. (2011) describe abstract and emotional concepts as being acquired and processed in the context of certain activities, including sensations in the body. In a similar vein, Kousta, Vigliocco, Vinson, Andrews and Del Campo (2011) propose an Embodied Theoretical View of Abstract Representation, proposing that abstract and concrete concepts bind different types of information, with concrete ones putting greater weight on sensorimotor information in the concept-learning environment (e.g., Pulvermuller, Hauk, Ilmoniemi, & Nikulin, 2005), while abstract ones put a greater weight on emotional information. This perspective is further developed by Ponari, Norbury, and Vigliocco (2018) who advance an Abstract-via-Emotion (AvE) hypothesis. It views emotion as a bootstrapping mechanism for learning abstract concepts, such that when learners are not fully able to use sensorimotor information they will likely use emotional information. This emotional information can be re-used through bootstrapping when learning subsequent abstract concepts based on those already acquired (see Moffat, Siakaluk, Sidhu & Pexman, 2015). While varying in proposed mechanisms and causes, this family of accounts shares a notion that emotional information has more impact on learning abstract words than concrete ones.

This theoretical stance finds support in mounting empirical evidence that abstract word learning, recognition and categorization is particularly affected by emotional experience (e.g., Newcombe, Campbell, Siakaluk, & Pexman, 2012; Siakaluk, Newcombe, Duffels, Li, Sidhu, Yap, & Pexman, 2016; Siakaluk, Knol, & Pexman, 2014). For instance, a regression study by Kousta et al. (2011) found that abstract words that tend to have emotional connotations are acquired earlier. Lund, Sidhu, & Pexman (2019) found that children aged 6 responded faster to positive abstract words in a lexical decision task, and children aged 7 responded faster to positive words regardless of concreteness. Ponari, Norbury, and Vigliocco (2017) found that valence and age affected lexical decision times: children aged 8–9 performed better with valenced abstract words compared to children aged 10–11, suggesting that emotional valence facilitates learning of abstract concepts in children. Specifically, Ponari, Norbury, and Vigliocco (2020) provided emotional vs. neutral vocabulary learning contexts to children aged 7-10 years and tested orthographic and semantic learning of novel concepts. In the semantic task, only children aged 7-9 years performed better in defining valenced abstract words than neutral ones. Since there was no effect of teaching strategy, Ponari et al. suggested that the emotional information in the learning context does not facilitate learning. Vigliocco, Ponari, and Norbury (2018) also found that after the age of 9, children make use of linguistic information in addition to emotional information as seen by less sensitivity to emotional valence. These findings suggest the differential engagement of sensorimotor and emotional information begins early in the time-course of language development. However, in adult learners (*M* age = 21.70, 20.37, 21.60, and 20.48 across four experiments) Muraki, Sidhu and Pexman (2020) found that in a syntactic classification task and a memory task, responses to abstract verbs that are related to emotional states in the body did not differ significantly from verbs related to mental states or non-embodied verbs. Muraki et al. suggested that this goes against the Affective Embodiment Account (AEA; Borghi et al., 2017; Kousta et al., 2011).

The main interest of this paper is whether the proposed differences in how concrete and abstract concepts are learned persist in proficient adult speakers of a language, and more specifically, during fast-paced incidental learning of novel words in a short experiment: see motivation below. A common way of experimentally testing such questions is to use word learning paradigms, where novel words are embedded into contexts (e.g., Saragi, Nation, &

Meister, 1978; Pellicer-Sanchéz & Schmitt, 2010). Typically, contexts are manipulated to represent relevant dimensions, and vocabulary post-tests are administered to estimate the quality of learning the novel word's form and meaning. In this study, we simultaneously manipulate concreteness of the intended meaning for the novel word and emotionality of its linguistic context.

These manipulations build on a few previous vocabulary learning studies. For example, concreteness of novel word denotations has shown influence in Ding, Liu and Yang's (2017) vocabulary learning study. Pseudowords were paired with concrete and abstract concepts in a contextual learning paradigm. After reading, participants' brain activity was recorded while performing a lexical decision task. In this task, the learned pseudowords served as primes for words that are either semantically related or unrelated. A smaller amplitude of the Late Positive Component (LPC), which shows awareness of semantic relationships between primes and target words (see Bouaffre & Faita-Ainseba, 2007) was observed for related concrete concepts relative to abstract ones. Since LPC is argued to correlate with processing difficulty, results were interpreted as showing support for the Extended Dual Coding Hypothesis, i.e., the learning of the concrete novel words was facilitated by the multiple types of information (imagery and verbal) compared to abstract ones. Additionally, Elgort and Warren (2014) explored the effect of concreteness in contextual vocabulary learning, along with other factors. Participants read a text where some words were replaced with novel words that have concrete or abstract denotations. Immediate post-tests of word knowledge showed that words with concrete denotations were learned better than words with abstract denotations, suggesting that the concreteness effect found in the established vocabulary also extends to novel word learning.

The role of context emotionality on novel word learning has been studied much less. A corpus study by Snefjella and Kuperman (2016) found that words that tend to occur in positive contexts come with reduced cognitive effort in lexical tasks – shorter recognition times, better memory recall and earlier age of acquisition – compared to words occurring in negative contexts. To our knowledge, only one study so far has used the novel word learning paradigm to investigate the role of context affect. Snefjella, Lana, and Kuperman (2020) embedded novel words in contexts that were kept consistently positive, neutral or negative for a given novel word and participant. They found that novel words absorbed emotional valence of the contexts in which those novel words occurred. Thus, an item *plurk* showed a reliably higher valence if encountered by a participant in positive contexts, lower if in neutral contexts, and even lower in negative contexts. Moreover, Snefjella et al. (2020) observed higher/medium/lower scores in post-tests of semantic knowledge for novel words learned in positive/neutral/negative contexts. This positivity advantage for novel words with concrete denotations is in line with the processing advantage established for existing positive words over negative ones (see review in Kuperman, Estes, Brysbaert, & Warriner, 2014) and for the advantage reported for existing words occurring in more positive contexts (Snefjella & Kuperman, 2016). Importantly for the present purposes, all novel words in Snefjella et al.'s (2020) study had concrete denotations (e.g., a tool, a piece of clothing) and thus could not shed light on whether emotional information of linguistic context is recruited particularly strongly in the learning of abstract rather than concrete concepts. This word concreteness x context affect interaction is implemented in the present study.

The present study

The goal of this study is to validate a long-standing notion of the interaction between affect and concreteness in word learning, with emotional information being more implicated in learning abstract words. Most of the empirical basis for related theoretical accounts has come from observational studies that document vocabulary acquisition and language development in children as well as empirical studies employing a lexical decision task to study concreteness processing in children (see the Introduction). We test the effects of emotional and sensorimotor information in a novel word learning paradigm, where factorial manipulations allow for a high degree of experimental control over both the input, the duration of learning, and the measurement of learning outcomes. Our target population is proficient adult native speakers of English, and the learning opportunities are confined to a relatively short experimental session. Observing a greater impact of emotional information on abstract rather than concrete word learning in this setup would contribute to the current understanding of vocabulary acquisition. Specifically, it would confirm that the proposed learning mechanisms are in place long after childhood and that they can be active instantaneously rather than over years of language use.

We build on previous word learning studies to factorially manipulate concreteness of word meaning and emotionality of that word's linguistic context and to assess theoretically predicted main effects of emotion and concreteness and their interaction. To this end, we modify Snefjella et al.'s (2020) study and place words with abstract (e.g., *temptation*) and concrete (e.g., *device*) intended meanings into informative contexts that are either positive, neutral, or negative. By keeping context emotionality consistent for each novel word within a given participant, we associate a specific emotional connotation with each learning occasion.

The predictions of the study are as follows. In line with the reported robust concreteness advantage, we expect novel words with concrete intended meanings to be learned better than those with abstract ones. We also expect context emotionality to be absorbed to some degree by novel words (that are originally devoid of either denotations or connotations) in a process typically labeled *semantic prosody* (see details in Snefjella & Kuperman, 2016; Winter, 2019). A critical prediction follows from theoretical accounts by Vigliocco et al. (2009) and Ponari, Norbury, & Vigliocco (2018). Specifically, we expect emotionally valenced contexts to influence learning of novel words with abstract denotations more so than learning of novel words with concrete denotations. Based on results of Snefjella et al. (2020), we refine this prediction. Namely, we expect novel words occurring in positive contexts to show better semantic learning and come with higher scores in post-tests of novel word form or meaning as compared to words learned in neutral or negative contexts. Furthermore, this positivity advantage is anticipated to be particularly salient in novel words with abstract connotations, because of a hypothesized greater reliance of abstract words on affective information (see above). In sum, embodied theories predict the main effect of concreteness (higher-quality learning for words with concrete denotations), the main effect of affect (higher-quality learning for words occurring in more positive contexts) and an interaction between the two (more positivity advantage in abstract rather than concrete words). We test these predictions in a large-sample online study set up in a novel word learning paradigm.

Methods

Participants

Eighty-eight participants were recruited from Amazon Mechanical Turk, an online crowdsourcing marketplace (mturk.com), and 198 through McMaster's undergraduate participant pool. This study was approved by McMaster's Research Ethics Board (2011-165). All participants were compensated with $4 USD or with course credit. Participants were removed if they indicated that their first language is not English, if they had a vision problem, hearing impairment, language disability, or learning disability, or if they had completed the study twice, resulting in 154 remaining participants (*M*age = 28.17, 53 male, 100 female, 1 other). The two participant pools did not differ in performance in any test, and so they are considered jointly below.

Materials

The setup of this study is a modification of Snefjella et al. (2020). It has a 3 x 2 design, with three levels of emotion of the linguistic context (positive, neutral, and negative) and two levels of concreteness of the novel word (abstract and concrete). Nine novel words were generated using the Wuggy software (Keuleers & Brysbaert, 2010) along with two homophones for each (e.g. plurk, plirk, plerk), and rated in a separate norming study, which demonstrated a valence range from 2.44 (rotch) to 4.22 (ceammy). The full list of novel words is available in Supplementary Materials S2. These novel words were used to replace abstract and concrete nouns in the target passages.

The passages were creating in triplets, such that each of the three passages contained two highly positive, highly negative or neutral words, while most of the carrier passage remained the same, see Table 1 for example stimuli. Moreover, all passages in a triplet had an identical final sentence containing one and the only occurrence of the novel word in a passage. Five of the triplets describe abstract concepts (e.g., temptation, psyche, religion, economics, chance) and four describe concrete concepts (e.g., boat, plant, kitchen appliance, clothing). For each novel word, five sets of triplets were created. Snefjella et al.'s stimuli for concrete concepts were used here, while abstract ones were developed anew. These triplets were rated in a separate norming study on Amazon Mechanical Turk, asking participants to rate the passages on a scale of 1-9 for valence, see Table 2. This norming study enabled us to select contexts reliably different in their emotionality, ($t(2126) = -4.42$, $p < 0.001$) and to ensure there are no significant differences between concrete and abstract conditions, see Table 11 in Supplementary Materials S1. Flesch Reading Ease and Flesch-Kincaid Grade Level estimates were collected from the computational tool Coh-Metrix to ensure that contexts are reasonably matched on readability ($t(2074.8) = -3.69$, $p = <.001$) see Table 12 and 13 in Supplementary Materials S2 (Graesser, McNamara, Louwerse, & Cai, 2004). The full list of passages can be found in Supplementary Materials S2.

For each participant, each novel word appeared in five passages. In total, each participant read 45 passages. The presentation of the passages was counterbalanced so that each participant saw each novel word in only one emotional type of context and always with the same intended (concrete or abstract) denotation. Thus, for one participant a novel word *plurk* would also occur five times in negative contexts and with a denotation "boat", while for another *plurk* would occur in neutral contexts and with a denotation "psyche".

Table 1

Example of stimuli for concrete and abstract concepts.

	Valence	Sentence	Denotation	Valence	Arousal	Flesch Reading Ease	Flesch-Kincaid Grade Level
Concrete	Positive	John loved the freedom of being on the lake. He took the NW over into the bay.	boat	7.00	4.29	93.73	2.30
	Neutral	John was finished and started the motor. He took the NW over into the bay.	boat	6.22	4.41	86.45	3.06

	Negative	John was almost drowned during the raging storm. He took the NW over into the bay.	boat	4.67	5.01	87.64	3.02
Abstract	Positive	The gorgeous building was full of light. He overcame a strong NW to take a picture.	temptation	5.75	3.85	78.75	4.39
	Neutral	The busy building was full of people. He overcame a strong NW to take a picture.	temptation	5.49	3.77	89.58	3.00
	Negative	The damaged building was full of blood. He overcame a strong NW to take a picture.	temptation	4.99	3.9	89.58	3.00

Table 2

Norming study ratings of valence, means and standard deviations in parentheses.

Condition	Abstract	Concrete
Negative	3.71 (2.39)	3.52 (2.03)
Neutral	5.50 (1.95)	5.62 (1.64)
Positive	6.63 (1.96)	6.86 (1.86)

Procedure

The experiment was administered as an online study. The experimental paradigm was that of incidental novel word learning, that is, participants were unaware that vocabulary post-tests were to be administered after the learning phase. Prior to beginning the experiment, participants provided informed consent to participate in the study. When beginning the experiment, participants received the instructions: “This is a study of different reading styles and the ability to understand texts. You will be shown a few short texts. Please read them carefully for comprehension.” In this part of the experiment, participants read 45 short passages, constituting the “learning” phase. In the second part, they were tested on their vocabulary learning through four tasks: orthographic choice, valence rating, definition prompting, and definition matching. Instructions appeared on the screen prior to each task. Details about each task are given below.

Post-tests

Below, the post-tests are presented in the order that they appear to the participant. In the orthographic choice task, word form knowledge was tested, while in the definition prompting and definition matching tasks semantic recall and recognition were tested (Laufer, Elder, Hill, & Congdon, 2004). Additionally, valence ratings to novel (initially meaningless) words enabled testing semantic prosody, i.e., the transfer of emotional information from linguistic context to the novel word.

Orthographic choice. The orthographic choice task measures learning of the forms of the novel words. Participants saw the novel words (e.g., *plurk*) along with homophones (e.g., *plirk*, *plerk*) and were instructed to indicate on the screen which novel words they recall reading. The baseline performance in tis task is 50%. See Supplementary Materials S2 for instructions.

Valence rating. The valence rating task measures the learned valence of the novel words. Participants were instructed to use an on-screen scale ranging from 1-9 to indicate the emotional connotation of the novel word or by pressing “0” to indicate that they had not seen this novel word. This task included filler novel words that were not included in the passage readings. See Supplementary Materials S2 for instructions.

Definition prompting. The definition prompting task measures semantic recall of the novel words. Participants were presented, one at a time, with novel words and fillers. For each word, they were asked to give a definition if they remember reading the word, and if not, to click the appropriate box indicating this word was not seen. For the seen novel words, hints were provided after each response, regardless if it was a hint or an indication that this word was not seen. The hints consisted of fragments of passages that this novel word was found in. When scoring this task, the first correct response was used, with a correct response using no hints earning 3 points, a correct response using 1 hint earning 2 points, and a correct response using 2 hints earning 1 point. If the correct response was not provided after 2 hints, 0 points were earned. See Supplementary Materials S2 for instructions. The baseline performance in this task, if responses are given randomly, is 0 points.

Definition matching. The definition matching task measures semantic recognition of the novel words. It is administered last so as not to confound the other tasks. The participants were provided with a list of 9 novel words and 9 foils and asked to match the words they read to the list containing 9 definitions and 9 foil definitions. See Supplementary Materials S2 for instructions. The baseline at-random performance in this task is 5.6%.

Individual difference measures

Participants filled out an online survey measuring individual differences. Participants were asked their age, gender, country of birth, country of residence, and highest level of education. They were also asked detailed questions about their language background: which language is most dominant (able to list up to five languages), and the order in which they learned their languages. If they were not born in an English-speaking country, they were asked about the age that they moved to one and the age that they began to learn English. They were also asked to rate, on a scale of 1-10, their proficiency in each of the following: speaking, understanding spoken language, and reading. Finally, participants reporting any vision problems, hearing impairments, language disabilities or learning disabilities were removed from analysis. The summary of individual difference measure responses can be found in Supplementary Materials S2.

Variables

Dependent variables. Vocabulary learning was measured through three post-tests, described in detail above: orthographic choice, definition prompting, and definition matching. The outcome of orthographic choice was response accuracy in percent correct, that of definition prompting was the average score in points (for scoring scheme see above), and that of definition matching was the percent of accurate matches between seen novel words and intended denotations. An additional test, the valence task, measured the potential learning of emotional connotation from context on a 1-9 scale.

Independent variables. One critical variable was whether the word's intended denotation was concrete or abstract. Another was emotional valence of linguistic contexts of novel words. A possible operationalization of context valence would be a tri-partite division of contexts into positive, neutral, and negative. However, a different operationalization is both theoretically advantageous and has greater explanatory power (Snefjella et al., 2020). Namely, we use the rating of valence for a specific novel word given by a specific participant as a predictor of their performance in vocabulary post-tests. This way, we tap into an individual experience of how valenced a given word is and associate it with the quality of learning those novel words. In all analyses below, this individual measure of valence explains more variance than the categorical three-level characterization of passages in terms of emotionality.

Control variables. Reading time for each passage is both a dependent and an independent variable in this study. We test the influence of context valence and concreteness on how long participants read those passages. We also include passage reading times as a co-variate in regression models predicting vocabulary post-tests. This step enables us to account for Schmidt's Noticing Hypothesis (1990; 2001), which proposed that longer reading times may indicate more attention paid to the stimuli and should therefore lead to better scores in post-tests. Reading times were measured for each participant and passage by collecting the time intervals between the appearance of the text on screen and the moment the participant clicked "Next" to proceed to the next passage.

Statistical considerations

Generalized linear mixed effect regression models (lme4 package, Bates, Mächler, Bolker, & Walker, 2015) were used in this analysis. These models allow for accounting for between-items and between-participants variability when estimating effects of covariates. All models were initially fitted with the full random-effects structure and downgraded if convergence errors were received. The lmerTest package (Kuznetsova et al., 2017) in the statistical platform R (R Core Team, 2019) was used to estimate p-values for fixed-effects with Satterthwaite's approximation for degrees of freedom. Library effects() (Fox, 2013; Fox & Weisberg, 2019) was used to visualize critical effects and interactions.

Results and Discussion

This section presents results for each post-test and then discusses them jointly.

Valence rating

A total of 6350 responses were recorded to the seen novel words. Participants accurately discriminated between seen and unseen novel words (89% accuracy) while giving valence ratings, in line with Snefjella et al.'s (2020) accuracy rates of 88% and 90% (experiments 1L, 1O). Table 3 summarizes mean valence ratings given to learned novel words, broken down by their emotionality and concreteness, see also Figure 1. As Table 3 demonstrates, a numerical effect of semantic prosody emerges in both abstract and concrete conditions: novel words appearing in positive, neutral or negative contexts acquired values of valence polarized in respective directions. The range and dispersion of valence ratings to four concrete denotations was similar to that observed in Snefjella et al.'s (2020) two experiments (1L, 1O) that used identical contexts (4.95 – 5.87, 5.04 – 5.77). Thus, the present experiment replicates prior results for the overlapping stimuli.

An important new finding is that for novel words with concrete denotations valence ratings had much more of a range between negative and positive contexts (5.09 – 5.83) compared to words with abstract denotations (5.3 – 5.5). This concreteness x context valence interaction was significant ($F(6331, 2) = 6.06$, $p = 0.002$), see Table 1 in Supplementary Materials S1. Moreover, post-hoc analyses (see Tables 2 and 3 in Supplementary Materials S1) revealed that the increase in novel word valence in abstract denotations determined by context valence was not significant ($p > 0.1$ in all contrasts).

These results drew a different picture from the one advocated by the theories above. In the present data, emotional polarity of the context had a much stronger effect on learning novel words with concrete denotations than abstract ones. This runs counter to several theories which expect a stronger sensitivity of abstract words to emotional information in the linguistic context (see the Introduction).

Table 3

Means of valence responses per condition. Standard deviations are reported in parentheses.

Condition	Abstract	Concrete
Negative	5.30 (2.30)	5.09 (2.14)
Neutral	5.39 (2.00)	5.41 (2.05)
Positive	5.52 (2.07)	5.83 (2.17)

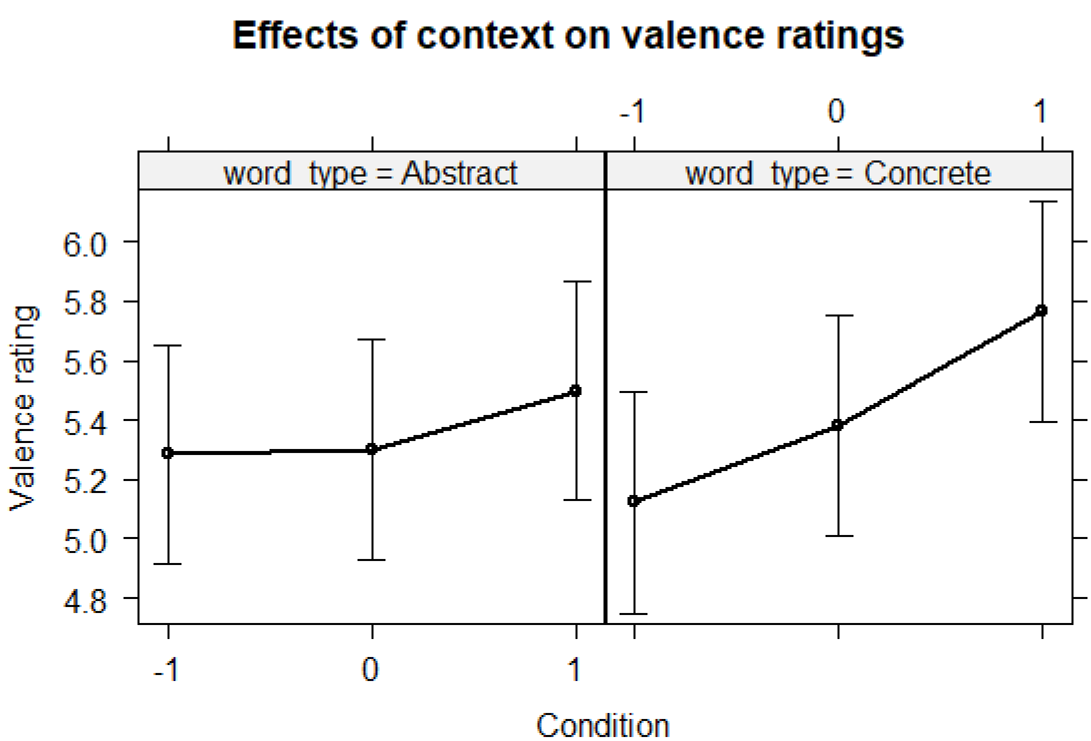

Figure 1. Partial effects of context valence on valence ratings to novel words, presented for abstract (left) and concrete (right) contexts. -1 stands for negative, 0 for neutral, and 1 for positive. Error bars represent standard errors.

Orthographic choice

The quality of learning the orthographic forms of novel words was measured in the orthographic choice post-test. Participants showed high accuracy (around 90%) in discriminating between seen novel words and their homophones (see Table 4 below), which is comparable to Snefjella et al.'s (2020) accuracy scores (81%, 81%, 86%, and 94% for experiments 1L, 1O, 2O, and 3O). A regression model fitted to orthographic choice responses (Table 4 in Supplementary Materials S1) did not indicate an effect of either individual valence ratings or concreteness, nor was there a reliable interaction of the two (all $p > 0.05$). That is, affective and sensorimotor characteristics of the learned novel words and their context did not affect orthographic form learning. This agrees with the findings of Snefjella et al. (2020) who did not observe effects of context emotionality on orthographic choice scores in words with concrete denotations. Notably, passage reading time showed a strong positive effect on the test scores, with participants who read materials in the learning phase longer having higher scores in this task ($\beta = 0.934$, $SE = 0.144$, $z = 6.496$, $p = <0.001$), in line with the Noticing Hypothesis (Schmidt, 1990; 2001).

Table 4

Orthographic choice scores by levels of context valence and novel word concreteness.

Condition	Abstract	Concrete
Negative	0.86 (0.34)	0.91 (0.29)
Neutral	0.91 (0.29)	0.88 (0.32)
Positive	0.90 (0.29)	0.91 (0.28)

Definition prompting

Semantic recall of the novel words was tested in the definition prompting post-test. Responses were scored on a scale of 0-3, with 3 being the highest possible score. In all conditions, the scores were much higher than the baseline of the test (0 points) suggesting that semantic learning did take place, see Table 5 with mean scores for each experimental cell. The regression model fitted to definition prompting scores (Table 5 in Supplementary Materials S1) revealed a concreteness advantage. Words with concrete denotations were learned better overall than words with abstract ones ($\beta = 0.234$, SE = 0.234, z = 0.104, p = 0.025). Importantly, the model did not indicate any effect of valence ratings on test scores, no was there an interaction between denotation concreteness and context valence (all $p > 0.05$). Emotionality of context did not affect this facet of semantic learning for either abstract or concrete words. Passage reading times showed an effect expected under the Noticing Hypothesis (Schmidt, 1990; 2001): a longer inspection of passages in the learning phase led to higher scores on this semantic knowledge test ($\beta = 0.119$, SE = 0.119, z = 0.048, p = 0.013).

Table 5

Concrete and abstract definition prompting scores per condition.

Condition	Abstract	Concrete
Negative	0.86 (1.08)	1.05 (1.12)
Neutral	0.79 (1.08)	1.00 (1.11)
Positive	0.90 (1.09)	1.11 (1.11)

Definition matching

Semantic recognition of the novel words was tested in the definition matching post-test. Overall, participants had 43% accuracy in recognizing seen novel words and matching them to correct denotations. This performance exceeded by far the baseline score of 5.6% that random responses to the test would have led to. A regression model confirmed the anticipated concreteness advantage (Table 6 in Supplementary Materials S1; $\beta = 1.785$, SE = 0.471, z = 0.471, p = <0.001). Novel words were matched to concrete denotations more accurately than to abstract ones (Table 6 below). Another important finding was that novel words learned in more positive contexts and associated with higher valence ratings showed higher definition matching scores ($\beta = 0.139$, SE = 0.055, z = 2.502, p = 0.012). While this positivity advantage was demonstrated in Snefjella et al. (2020) for concrete denotations, here we observed it in both concrete and abstract conditions. The definition matching score for a novel word with the lowest valence rating was estimated to be about 0.2 points lower than for a novel word with the highest valence rating. Crucially, this valence effect did not interact reliably with whether the novel word's intended denotation was concrete or abstract, see Figure 2 (F(1, 2 = 0.55, p = > 0.1).

That is, (a) positive contexts led to better semantic learning and (b) the strength of affective support for learning was equal for words with denotations that are (e.g., tool) or are not (e.g., psyche) directly linked with sensorimotor experiences.

Table 6

Concrete and abstract definition matching scores per condition.

Condition	Abstract	Concrete
Negative	0.37 (0.48)	0.53 (0.51)

Neutral	0.33 (0.47)	0.51 (0.50)
Positive	0.35 (0.48)	0.59 (0.49)

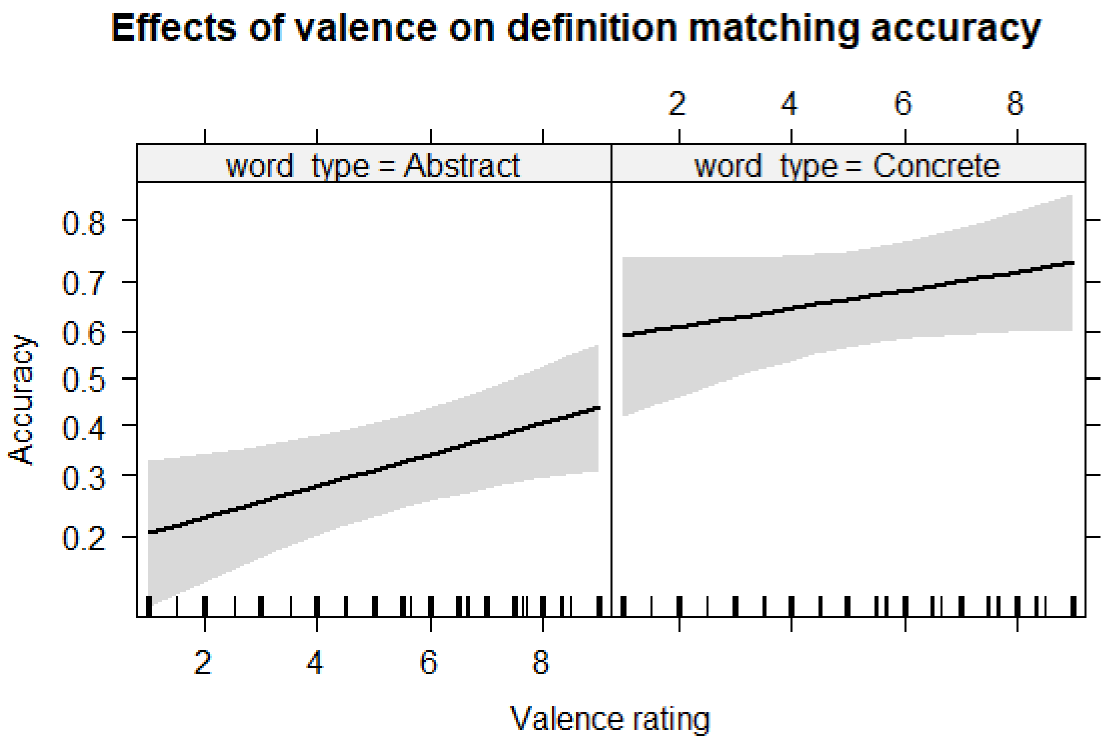

Figure 2. Abstract and concrete definition matching accuracy by individual valence ratings.

Reading times

Reading times were collected from each passage and used as a dependent variable. A regression model (Table 7 in Supplementary Materials S1) showed no effect of valence ($F(1172.37, 1) = 4.47$, $p = 0.035$) or concreteness ($F(78.35, 1) = 2.93$, $p = 0.09$) on passage reading times, nor was there an interaction of the two factors ($F(1135.60, 1) = 0.51$, $p = 0.47$). We conclude that the amount of noticing during the learning phase is unaffected by affective or sensorimotor dimensions of the novel words and their contexts.

General Discussion

The goal of this study was to investigate a family of theoretical proposals which argue that emotion is recruited to provide grounding for abstract concepts more than it does for concrete concepts (Barsalou, 2009; Kousta et al., 2011; Ponari et al., 2018). This mechanism is argued to account for acquisition of abstract concepts in childhood and has found most support in studies of children varying in age as well as corpus studies. We tested this claim in proficient adult native speakers of English in a brief experimental session. Specifically, we manipulated the valence of contextual information surrounding novel words that were further manipulated to have either concrete or abstract denotations. A large-scale experiment in an incidental vocabulary learning paradigm had five abstract and four concrete nouns that were replaced with novel words in five contexts for each word. Each participant saw each novel word in five consistently positive, neutral, or negative contexts, which can be used to infer a consistently concrete or abstract denotation for that word. Following the reading phase, participants were tested on their vocabulary learning via tests of orthographic and semantic knowledge.

The motivation for selecting an adult population rather than children and examining fast-paced learning with a few learning opportunities rather than a result of natural language learning was to study whether proposed learning mechanisms are in place throughout the lifespan and whether they are accessible and active "on a moment's notice", over a few exposures to a novel word. Critically, several theories of embodied word learning predict that emotionality of linguistic context is more influential for learning novel words with abstract rather than concrete denotations (see the Introduction). The present predictions consisted of an expected learning advantage to novel words with concrete denotations (supported by much prior research, see the

Introduction) and to novel words occurring in more positive contexts (see Snefjella & Kuperman, 2016; Snefjella et al., 2020). We discuss these predictions one by one.

The well-established concreteness advantage in the quality of learning was evident in both semantic knowledge tasks. While both concrete and abstract denotations (e.g., *boat* vs *psyche*) resulted in scores well above chance for both recall (definition prompting) and recognition (definition matching), scores were consistently higher for words with concrete denotations.

The tendency of novel words learned in more positive contexts to come with a better quality of semantic learning (Snefjella et al., 2020) was replicated here as well, in the definition matching task. The effect was equally strong for abstract and concrete words. No effect of context valence was observed in the definition prompting task. We also note that neither the concreteness nor the positivity advantage surfaced in the orthographic learning quality or in the inspection time of passages during the learning phase. Apparently, emotional and sensorimotor dimensions of the learning events have a focused influence on semantic rather than form learning, and more in concept recognition than recall.

The present study answers in the negative its central question, whether affective information conveyed by linguistic context influences learning concrete and abstract words differently. While either concreteness of denotation or context valence or both showed an impact on semantic knowledge, neither semantic task revealed an interaction between these two factors. Context valence was equally influential for concrete and abstract denotations in definition matching (Figure 2) and equally ineffective for the two types of denotations in definition prompting.

The piece of evidence that is perhaps most difficult to reconcile with the hypothesized role of emotion in abstract word learning is the valence rating task. Novel words with concrete denotations were the ones that absorbed affect of linguistic contexts the most. After the learning phase, they were judged as more positive, neutral or negative in accordance with the contexts in which they occurred. Thus, semantic prosody, or the transfer of connotations from context to a word, demonstrably took place in these stimuli (in line with Snefjella & Kuperman, 2016; Snefjella et al., 2020; Winter, 2019). Conversely, novel words with abstract denotations were judged to have the same neutral valence, even though – like their concrete counterparts – they were embedded in contexts with different affective polarity.

This goes against several theoretical accounts (see the Introduction) which argue that emotional information is particularly required and recruited when abstract concepts are learned. We outline some of the possible reasons for this discrepancy. An important deliberate deviation of our study from the empirical evidence that supports those accounts is its population (adults vs children) and the time scale of learning (a brief experimental session vs years of accumulated linguistic knowledge). In a sense, our experimental setup presents conditions under which the critical interaction (context valence x word concreteness) is the least likely to emerge. This is because with age the use of affective information in learning is either supplemented or replaced by the use of linguistic information: see Ponari et al.'s (2018) contrast between 9 and 10 year old children. Also, the tightly controlled experimental stimuli with novel words come in quick succession, possibly impeding memory consolidation processes. Moreover, presented for reading on the screen, outside of a natural communicative environment, these stimuli are more difficult to link to either sensorimotor or affective information for the learner.

Thus, statistical null effects of the critical interaction in our data do not disconfirm the theories arguing for specific learning mechanisms for abstract and concrete words. However, our findings restrict the scope of predictions that these theories make. Specifically, the present data suggest that at some point in the developmental trajectory – contingent perhaps on age, language experience, emotion regulation, and world knowledge – vocabulary acquisition of abstract concepts transitions from a heavy reliance on available emotional information to the disuse of this information. Charting when and explaining how this transition happens is a theoretical and empirical goal for future research.

An additional observation that theories of word learning need to account for is that acquisition of concrete concepts does rely on emotional information in adult proficient learners, with an effect noticeable over a few encounters with the novel word. Whether this reliance is absent in early vocabulary acquisition and rather develops with age or it is present at all stages of vocabulary development is also a topic for further examination.

This study reveals that novel word learning is a complex process demonstrably influenced by semantic dimensions of both the novel word itself and those of its linguistic contexts. We demonstrate that sensorimotor and emotional information that novel words and their contexts encode is an influential factor in word learning, even in proficient adult speakers of a language and over as little as 5 exposures to the word. We also show that the interplay of sources of sensorimotor and emotional information is different from the one hypothesized by several prominent theories of vocabulary acquisition, in ways that warrant further investigation.

Summary and Conclusions

This study provides novel insight for theories of embodied cognition, particularly in identifying the degree to which concepts depend on experiential information. As outlined in the Introduction, there is disagreement among theories of embodied cognition on how dependent lexical processing is on sensorimotor systems, with several accounts suggesting that in addition to sensorimotor information, linguistic context and affect can influence lexical processing (Vigliocco et al., 2009; Kousta et al., 2009; Kousta et al., 2011). The current study experimentally investigated this claim using a word learning paradigm, where novel words with denotations varying in concreteness were embedded in linguistic contexts that varied in emotionality. After reading, semantic and orthographic learning of the novel words was assessed.

The results of the current study support a partial dependence on sensorimotor systems, in line with weak embodiment accounts. While there was a concreteness advantage in both semantic learning post-tests, which indicates a critical role of sensorimotor systems in lexical processing, novel words denotating abstract concepts were also successfully learned. According to Vigliocco et al. (2009), learning of both concrete and abstract words utilizes both experiential (sensorimotor and affective) and linguistic information. The current study is in line with this account, as novel words denoting both concrete and abstract concepts were successfully learned using the surrounding linguistic context, regardless of context emotionality and concreteness of denotations.

Conversely, Kousta et al. (2011) proposed that concrete and abstract concepts bind different information: concrete concepts depend on sensorimotor information, while abstract concepts put greater weight on affective information. The current study did not show an interaction between concreteness or denotation in the semantic learning post-tests. Additionally, the valence rating post-test showed that novel words denoting concrete concepts were more sensitive to the valence of the linguistic contexts that novel words occurred in. This goes against Kousta et al. (2011), who proposed that affective information would be utilized more for abstract concepts. However, this conflicting evidence may be due to several factors (as mentioned in the Discussion above): First, our study offers a very brief time scale of learning where participants learn novel words during a short reading session, and are tested immediately after. While it is naturalistic in the sense that novel words are often learned during reading in adulthood, it does not accurately represent this learning. The nine novel words in our study are presented simultaneously in one session, in independent, varying contexts, while a more natural approach to contextual word learning might occur when encountering a single novel word, in several contexts over a large stretch of time before encoding a meaning for this word. The pace of the current study may affect learning, giving less opportunity to utilize context in an effective way. Second, our study tests proficient adult speakers of English. Previous studies have held a focus on word learning in children, where abstract concepts are often being learned for the first time. This study suggests that the account outlined by Kousta et al. (2011) does not extend to adult learners, at least not under the current experimental conditions.

In sum, this study provides constrained evidence that experiential information, including sensorimotor and emotional information, and linguistic information contributes to word representations, in line with weak embodied theories of cognition. By using the surrounding linguistic context, novel words denoting both concrete and abstract concepts were successfully learned, both in terms of valence and semantic meaning. Participants were able to associate novel words with surrounding linguistic context to aid with semantic memory of these words.

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Supplementary Materials

S1

Regression Models

Table 1

Model of valence ratings for words with concrete and abstract denotations

	Estimate	Std. Error	df	t value	P value
(Intercept)	5.284	0.188	23.051	28.083	<0.001
Condition 0	0.016	0.075	6288.642	0.217	0.828
Condition 1	0.215	0.072	6292.194	2.970	0.003
Concrete	-0.163	0.082	6308.367	-1.972	0.049
Condition 0: Concrete	0.246	0.123	6325.432	1.998	0.046
Condition 1: Concrete	0.431	0.124	6332.954	3.469	0.001

Note. Standard deviation of the by-participant intercepts is 1.38, and standard deviation of the word intercepts is 0.43. N = 152, number of observations = 6350. The reference level for condition is -1 (negative), while 0 stands for neutral and 1 for positive. The reference level for denotation is abstract.

Table 2

Model of valence ratings for words with abstract denotations

	Estimate	Std. Error	df	t value	P value
(Intercept)	5.237	0.225	46.568	23.284	<0.001
Type SONA	0.115	0.238	147.678	0.485	0.628
Condition 0	0.025	0.081	3546.419	0.307	0.759
Condition 1	0.150	0.078	3552.102	1.927	0.054 .

Note. Standard deviation of the by-participant intercepts is 1.42, and standard deviation of the word intercepts is 0.41. N = 152, number of observations = 3585. The reference level for condition is -1 (negative), while 0 stands for neutral and 1 for positive. The reference level for type is MTurk.

Table 3

Model of valence ratings for words with concrete denotations

	Estimate	Std. Error	df	t value	P value
(Intercept)	5.109	0.231	53.500	22.142	<0.001
Type SONA	0.071	0.247	149.038	0.288	0.773
Condition 0	0.162	0.097	2799.572	1.666	0.096 .

Condition 1	0.532	0.102	2801.225	5.231	<0.001

Note. Standard deviation of the subject intercepts is 1.48, and standard deviation of the word intercepts is 0.40. N = 152, number of observations = 2870. The reference level for condition is -1 (negative), while 0 stands for neutral and 1 for positive. The reference level for type is MTurk.

Table 4

Model of orthographic choice scores by individual valence ratings

	Estimate	**Std. Error**	**z value**	**P value**
(Intercept)	-0.274	0.630	-0.436	0.663
Valence rating	0.009	0.070	0.122	0.903
Concrete	0.287	0.582	0.493	0.622
Reading time	0.934	0.144	6.496	<0.001
Valence rating: Concrete	-0.015	0.101	-0.147	0.883

Note. Standard deviation of the by-participant intercepts is 1.11. N = 152, number of observations = 1283. The reference level for denotation is abstract. The reference level for denotation is abstract.

Table 5

Model of definition prompting scores by individual valence ratings

	Estimate	**Std. Error**	**z value**	**P value**
(Intercept)	-1.285	0.210	-6.118	<0.001
Valence rating	0.004	0.013	0.344	0.731
Concrete	0.234	0.234	0.104	0.025
Reading time	0.119	0.119	0.048	0.013
Valence rating: Concrete	-0.002	0.018	-0.002	0.891

Note. Standard deviation of the by-participant intercepts is 1.44 and standard deviation of the word intercepts is 0.07. N = 155, number of observations = 3595. The reference level for denotation is abstract.

Table 6

Model of definition matching scores by individual valence ratings

	Estimate	**Std. Error**	**z value**	**P value**
(Intercept)	-4.623	0.660	-7.005	<0.001
Valence rating	0.139	0.055	2.502	0.012

Concrete	1.785	0.471	0.471	<0.001
Reading time	0.871	0.165	5.275	<0.001
Valence rating: Concrete	-0.058	0.081	-0.723	0.469

Note. Standard deviation of the by-participant intercepts is 1.52 and standard deviation of the word intercepts is 0.32. N = 141, number of observations = 1156. The reference level for denotation is abstract.

Table 7

Model of reading times

	Estimate	**Std. Error**	**df**	**t value**	**P value**
(Intercept)	3.240	0.082	224.560	39.282	<0.001
Valence rating	0.011	0.009	1156.426	1.194	0.233
Concrete	-0.141	0.083	78.355	-1.710	0.091 .
Valence rating: Concrete	0.009	0.013	1135.597	0.711	0.477

Note. Standard deviation of the by-participant intercepts is 0.74 and standard deviation of denotation intercepts is 0.05. N = 159, number of observations = 1283. The reference level for de notation is abstract.

S2

Individual differences

Participants answered a short questionnaire about their language background. The native language of all participants was English. However, it should be noted that many participants were multilingual. The second language of some participants included: Arabic (1), American Sign Language (2), Canto-Malay (1), Cantonese (4), Czech (1), Farsi (1), French (20), German (4), Harari (1), Hebrew (3), Hindi (1), Ilocano (1), Indonesian (1), Italian (2), Japanese (1), Klingon (1), Korean (1), Mandarin (1), Polish (2), Portuguese (2), Serbian (2), Somali (2), Spanish (8), Tamil (2), Urdu (1). The third language of some participants included: American Sign Language (1), French (28), German (4), Hindi (1), Italian (3), Japanese (1), Mandarin (5), Punjabi (1), Slovak (1), Spanish (3), Tagalog (1), Urdu (1), Welsh (1). The third language of some participants included: American Sign Language (3), French (8), Hebrew (1), Hindi (2), Italian (1), Japanese (2), Mandarin (2), Spanish (5), Yiddish (1). The fourth language of some participants included: American Sign Language (1), French (3), German (1), Hindustani (1), Italian (2), Russian (2), Spanish (1), Turkish (2).

Participants also answered a short questionnaire about their English language skills, including speaking, reading, and understanding, on a scale of 1 – 10, with 1 being the lowest and 10 the highest. They also answered a question about the education level they had completed at the time of participation. The results are summarized below:

Table 8

Participant self-ratings in English proficiency skills.

Skills	**Mean**
Speaking	9.75 (0.91)

Reading	9.71 (0.92)
Understanding	9.75 (0.91)

Note. Standard Deviations (SD) are presented in parentheses.

Table 9

Participant education level.

Education	Number of participants
High school	59
Some college	14
College	13
Some university	37
University	30
Masters	8

Table 11

ANOVA summary of differences between conditions and type of stimuli

	Estimate	Std. Error	df	t value	p value
(Intercept)	3.727	0.216	116.233	17.243	0.000
Type Concrete	-0.193	0.305	114.895	-0.634	0.527
Condition Neutral	1.779	0.305	114.907	5.836	0.000
Condition Positive	2.898	0.304	114.206	9.522	0.000
Type Concrete: Condition Neutral	0.310	0.431	114.440	0.719	0.474
Type Concrete: Condition Positive	0.410	0.430	113.488	0.953	0.342

Note. Standard deviation of the input is 0.86 and standard deviation of the residual is 1.78. Number of observations = 2235. The reference level for type is abstract.

Table 12

Model of Coh-Metrix readability scores

	Estimate	Std. Error	df	t value	p value
(Intercept)	3.159	0.135	128.973	23.393	0.000

Type Concrete	0.222	0.203	129.097	1.094	0.276
Condition Neutral	2.417	0.191	129.296	12.650	0.000
Condition Positive	3.768	0.191	128.322	19.757	0.000
Type Concrete: Condition Neutral	-0.314	0.286	128.743	-1.096	0.275
Type Concrete: Condition Positive	-0.100	0.287	129.118	-0.349	0.728

Table 13

ANOVA summary of Coh-Metrix readability scores

	Sum Sq	**Mean Sq**	**NumDF**	**DenDF**	**F value**	**P value**
Type	1.67	1.67	1	128.87	0.513	0.475
Condition	2229.29	1114.65	2	128.87	341.03	<0.001
Type: Condition	4.09	2.04	2	128.87	0.63	0.536

S3

Full list of stimuli

Table 10

Full list of novel words.

Plurk
Gloar
Ceammy
Rotch
Mernt
Aunith
Flyph
Cruce
Neak

Post-test instructions

Valence rating. For the next task, a word will appear on the screen. Some of the words will be the new words you read before. You will use a scale to rate how you feel while reading each word. The scale ranges from 1 (unhappy) to 9 (happy). At one extreme of this scale, you are happy, pleased, satisfied, contented, hopeful. When you feel completely happy you should indicate this by selecting 9. The other end of the scale is when you feel completely unhappy, annoyed, unsatisfied, melancholic, despaired, or bored. You can indicate feeling completely unhappy by selecting 1. You can describe intermediate feelings of pleasure by selecting any of the other digits from 2-8. If you feel completely neutral, neither happy nor sad, you would select 5. If the word is not a word you read before, indicate so by selecting the appropriate box.

Orthographic choice. For the next task, some strings of letters will appear on the screen. Please indicate whether the string is one of the new words you just read. Try to do this as fast and accurately as possible.

Definition prompting. In this task you will try to give a definition of the unfamiliar words from the passages. Your definition should be similar to what you might find in a dictionary. For example, if you had read the passage ‘John was in his studio. He spread colors with his moffle.’ you might guess that a moffle is ‘a kind of paintbrush.’ Once you have tried to give a definition, you may or may not be given a hint, after which you can then give another definition. Try to come up with your definition using as few hints as possible. If you don't think you read the word in the passages, click ‘I didn't read this word.’

Definition matching. This is a definition matching task. Please indicate which definition is the most correct for each word by filling in the boxes with the number of the best-fitting definition on the right. If a word or a definition is not from what you read earlier, leave a blank.

Full list of stimuli

Condition	Sentence
Positive	In an interesting psychology class, Lisa's teacher introduced a very cool concept. He taught about NW for two classes.
Negative	In a boring psychology class, Lisa's teacher introduced a very difficult concept. He taught about NW for two classes.
Neutral	In a general psychology class, Lisa's teacher introduced a very technical concept. He taught about NW for two classes.
Positive	Tom was thrilled that Anna happily agreed to go on a date with him. The need for love is deeply buried in our NW.
Negative	Tom was upset that Anna angrily rejected going on a date with him. The need for love is deeply buried in our NW.
Neutral	Tom was content that Anna quickly agreed to go on a date with him. The need for love is deeply buried in our NW.
Positive	Friendship leads to happiness. This notion is rooted deep in the NW of humans.
Negative	Alcoholism leads to loneliness. This notion is rooted deep in the NW of humans.
Neutral	Work leads to development. This notion is rooted deep in the NW of humans.
Positive	My lovely therapist makes me relax. Studying NW is her profession.
Negative	My cranky therapist makes me grouchy. Studying NW is her profession.
Neutral	My clinical therapist makes me change. Studying NW is her profession.
Positive	After a wholesome experience in high school, Emma enjoyed reading books about psychology. The human NW is an intricate notion.
Negative	After a crappy experience in high school, Emma dreaded reading books about psychology. The human NW is an intricate notion.
Neutral	After a normal experience in high school, Emma continued reading books about psychology. The human NW is an intricate notion.

Positive	Emily found attending the colourful church to be enjoyable. She went because NW was important to her parents.
Negative	Emily found attending the atrocious church to be dreadful. She went because NW was important to her parents.
Neutral	Emily found attending the average church to be rudimentary. She went because NW was important to her parents.
Positive	John's loyal friend was always optimistic after Sunday service. He realized that NW requires real devotion.
Negative	John's sullen friend was always disappointed after Sunday service. He realized that NW requires real devotion.
Neutral	John's new friend was always quiet after Sunday service. He realized that NW requires real devotion.
Positive	Megan's supportive family was encouraging her to become a nun. The family valued NW above all else.
Negative	Megan's awful family was battering her to become a nun. The family valued NW above all else.
Neutral	Megan's large family was enabling her to become a nun. The family valued NW above all else.
Positive	A friend took me to a beautiful wedding ceremony at a welcoming temple. It made me see that NW is not only about praying.
Negative	A jerk took me to a boring wedding ceremony at a weird temple. It made me see that NW is not only about praying.
Neutral	A co-worker took me to a wedding ceremony at a nearby temple. It made me see that NW is not only about praying.
Positive	Cole's priest was always generous and blissful. This influenced Cole's view of NW greatly.
Negative	Cole's priest was always stubborn and uncooperative. This influenced Cole's view of NW greatly.
Neutral	Cole's priest was always dawdling and mingling. This influenced Cole's view of NW greatly.
Positive	After completing a splendid labour markets course, the man felt satisfaction. He took NW as his elective.
Negative	After completing a useless labour markets course, the man felt bitter. He took NW as his elective.
Neutral	After completing a quick labour markets course, the man felt enabled. He took NW as his elective.
Positive	Supply, demand and equilibrium are all very remarkable topics that Mark finds gratifying. The subject matter of NW is new to him.
Negative	Supply, demand and equilibrium are all very difficult topics that Mark finds terrible. The subject matter of NW is new to him.
Neutral	Supply, demand and equilibrium are all very extensive topics that Mark finds overlapping. The subject matter of NW is new to him.
Positive	Ashley loves her extraordinary job in an accounting firm. She took a Masters degree in NW at Yale.
Negative	Ashley despises her depressing job in an accounting firm. She took a Masters degree in NW at Yale.
Neutral	Ashley attends her necessary job in an accounting firm. She took a Masters degree in NW at Yale.
Positive	The caring prime minister created opportunities for small businesses to thrive. The topic of NW plays a big role in governmental decisions.
Negative	The evil prime minister decided to shut down several small businesses. The topic of NW plays a big role in government policy.
Neutral	The current prime minister decided that small businesses are financially important. The topic of NW plays a big role in government policy.
Positive	Matt's friendly boss had a great idea. He wants Matt to learn theories of NW to increase company production and profit.
Negative	Matt's crummy boss had a frustrating idea. He wants Matt to learn theories of NW to increase company production and profit.
Neutral	Matt's current boss had a random idea. He wants Matt to learn theories of NW to increase company production and profit.
Positive	Joey has just learned about a fun event in a prestigious restaurant. He wondered if people felt a NW to go.

Negative	Joey has just learned about a terrible event in a dirty restaurant. He wondered if people felt a NW to go.
Neutral	Joey has just learned about a short event in a nearby restaurant. He wondered if people felt a NW to go.
Positive	I was so pleased that I approved his offer. I resisted the NW to call my mom and tell her.
Negative	I was so upset that I rejected his offer. I resisted the NW to call my mom and tell her.
Neutral	I was so busy that I inflated his offer. I resisted the NW to call my mom and tell her.
Positive	Rachel went with her gracious friends for a refreshing dinner. The NW to get chocolate cake for dessert was overwhelming.
Negative	Rachel went with her awkward friends for a terrible dinner. The NW to get chocolate cake for dessert was overwhelming.
Neutral	Rachel went with her work friends for a regular dinner. The NW to get chocolate cake for dessert was overwhelming.
Positive	Dan's bright room was full of lovely things. The NW to buy more was hard to resist.
Negative	Dan's dark room was full of junky things. The NW to buy more was hard to resist.
Neutral	Dan's simple room was full of custom things. The NW to buy more was hard to resist.
Positive	The gorgeous building was full of light. He overcame a strong NW to take a picture.
Negative	The damaged building was full of blood. He overcame a strong NW to take a picture.
Neutral	The busy building was full of people. He overcame a strong NW to take a picture.
Positive	Chris excitedly looked at the fancy letter of acceptance from the university. He thought this would be his NW to get a real education.
Negative	Chris cried as he looked at the horrible letter of rejection from the university. He thought this would be his NW to get a real education.
Neutral	Chris calmly looked at the handwritten letter from the university. He thought this would be his NW to get a real education.
Positive	Looking up at the beautiful sky, the group of friends smiled. The forecast said that the NW of rainy weather was high.
Negative	Looking up at the darkening sky, the tired worker frowned. The forecast said that the NW of rainy weather was high.
Neutral	Looking up at the cloudy sky, the man nodded. The forecast said that the NW of rainy weather was high.
Positive	The happy couple explored the interesting city. They didn't get a NW to stop by the post office.
Negative	The miserable couple explored the boring city. They didn't get a NW to stop by the post office.
Neutral	The jetlagged couple explored the new city. They didn't get a NW to stop by the post office.
Positive	The funny comedian wandered off during the rehearsal. There's a good NW that he will be found.
Negative	The disgusting murderer wandered off during the court hearing. There's a good NW that he will be found.
Neutral	The young accountant wandered off during the meeting. There's a good NW that he will be found.
Positive	Wendy loved the sound of the clapping audience. She had one more NW to prove herself.
Negative	Wendy hated the sound of the booing audience. She had one more NW to prove herself.
Neutral	Wendy listened to the sound of the loud audience. She had one more NW to prove herself.
Positive	John only buys the best for his kitchen. He took the NW from the box and put it on the counter.
Negative	John only buys second-hand junk for his kitchen. He took the NW from the box and put it on the counter.
Neutral	John only buys some steel stuff for his kitchen. He took the NW from the box and put it on the counter.
Positive	Mary adored making home cooked meals. John gave her a NW as a gift.
Negative	Mary hated cooking and dirty dishes. John gave her a NW as a gift.
Neutral	Mary had some room on her hallway shelf. John gave her a NW as a gift.
Positive	The delicious dessert was cooked to perfection. John had used a NW to make it.

Negative	The horrible steak was burned to ashes. John had used a NW to make it.
Neutral	The second plate was ready by seven. John had used a NW to make it.
Positive	It was great to make a gourmet meal for all her friends. Anyone that has a NW can cook for a crowd.
Negative	It was awful to slave over a dinner for all these strangers. Anyone that has a NW can cook for a crowd.
Neutral	It was a requirement to make food for ten people. Anyone that has a NW can cook for a crowd.
Positive	The newly renovated kitchen looked gorgeous. They installed the NW above the counter.
Negative	The old makeshift kitchen needed repairs. They installed the NW above the counter.
Neutral	The medium sized kitchen had unused space. They installed the NW above the counter.
Positive	The colours matched her beautiful eyes. She wore the NW all the time.
Negative	She was poor and had almost nothing. She wore the NW all the time.
Neutral	The temperature there wasn't all that warm. She wore the NW all the time.
Positive	He dressed to look sexy and tough. He sewed a patch on the NW that day.
Negative	He ripped a hole in it when he fell. He sewed a patch on the NW that day.
Neutral	He noticed a small gap in the fabric. He sewed a patch on the NW that day.
Positive	The friends all thought they looked really cute. The uniform had a NW they had to wear.
Negative	The employees all hated that they looked ridiculous. The uniform had a NW they had to wear.
Neutral	The people always got changed before work. The uniform had a NW they had to wear.
Positive	She was shopping in the best boutique. She looked over the NW in the mirror.
Negative	She despaired that everything made her look ugly. She looked over the NW in the mirror.
Neutral	She tried on a few different outfits. She looked over the NW in the mirror.
Positive	Freshly cleaned clothes smell great. He took a NW out of the dryer and sniffed it.
Negative	He was afraid it would always smell terrible. He took the NW out of the dryer and sniffed it.
Neutral	He checked to make sure it had worked. He took the NW out of the dryer and sniffed it.
Positive	Mary thought her garden looked pretty. It was full of NW which grew everywhere.
Negative	Mary avoided that awful creepy path. It was full of NW which grew everywhere.
Neutral	Mary thought her lawn might need watering. It was full of NW which grew everywhere.
Positive	Growing things made John feel happy. He watered the NW all the time.
Negative	John had a bad habit of killing his houseplants. He watered the NW all the time.
Neutral	John decided to do some necessary chores. He watered the NW all the time.
Positive	Gardeners made a list of the most beneficial herbs. Many of them rank NW the highest.
Negative	Gardeners made a list of the most destructive weeds. Many of them rank NW the highest.
Neutral	Gardeners made a list of the most common tubers. Many of them rank NW the highest.
Positive	Mary was walking through the pretty forest. She picked and ate a NW right there.
Negative	Mary didn't know it was poisonous. She picked and ate a NW right there.
Neutral	Mary went through some a wooded area. She picked and ate a NW right there.
Positive	John knew it was covered with soft fuzz. He touched the NW on the leaf.
Negative	John forgot that it would give him a dreadful rash. He touched the NW on the leaf.
Neutral	John brushed against some branches as he walked. He touched the NW on the leaf.
Positive	John loved the freedom of being on the lake. He took the NW over into the bay.
Negative	John was almost drowned during the raging storm. He took the NW over into the bay.
Neutral	John was finished and started the motor. He took the NW over into the bay.
Positive	The water was crystal clear and refreshing. Mary jumped out and pulled the NW to shore.
Negative	The water was murky and polluted. Mary jumped out and pulled the NW to shore.

Neutral	The water was about two feet deep. Mary jumped out and pulled the NW to shore.
Positive	Steering was easy and Mary learned fast. She piloted the NW right into the dock.
Negative	Steering was hard and Mary made a mistake. She piloted the NW right into the dock.
Neutral	Steering was something Mary was required to do. She piloted the NW right into the dock.
Positive	The deck was clean and full of happy vacationers. Mary stepped onto the NW and went to the bow.
Negative	The deck was filthy and everyone looked miserable. Mary stepped onto the NW and went to the bow.
Neutral	The deck was full of boxes of cargo and ropes. Mary stepped onto the NW and went to the bow.
Positive	A pod of dolphins playfully swam with us. I jumped off the NW into the water with them.
Negative	The survivors fled the raging fire. I jumped off the NW into the water with them.
Neutral	The divers put on their goggles and got in. I jumped off the NW into the water with them.