That means something to me: how linguistic and emotional experience affect the acquisition,
representation and processing of novel abstract concepts

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Abstract

We used a novel linguistic training paradigm to investigate the experience-dependent acquisition, representation and processing of novel emotional and neutral abstract concepts. Participants engaged in mental imagery ($n = 32$) or lexico-semantic rephrasing ($n = 34$) of linguistic material during five training sessions and successfully learned the novel abstract concepts. Feature production after training showed that specifically emotion features enriched the emotional concepts' representations. Unexpectedly, for participants engaging in a vivid mental imagery during training a higher semantic richness of the acquired emotional concepts slowed down lexical decisions. Rephrasing, in turn, promoted a better learning and processing performance than imagery, probably due to stronger established lexical associations. Our results confirm the importance of emotional and linguistic experience and additional deep lexico-semantic processing for the acquisition, representation and processing of abstract concepts.

Keywords: abstract concepts, grounded cognition, word learning, lexical decision, feature production

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New knowledge comes with experience. During the global COVID-19 pandemic, we experienced novel words such as *covidiot* (someone who ignores public health measures; Roig–Marín, 2020). When we encounter such a novel word, our semantic memory stores the information we collect during our experience with the word’s referent and binds it in form of a concept (Martin & Chao, 2001). The experience we initially gain with the novel concept’s referent is generalized over time and space during the consolidation of the novel concept into our semantic memory (Lambon-Ralph et al., 2016; Pulvermüller, 2013). According to *grounded cognition theory*, word representation and processing after acquisition taps into the same resources as experience via simulations (Barsalou, 2008).

It is easy to put a finger on which type of experience is involved in learning, representing and processing concrete words, like *dog* or *jump*. The referents of concrete concepts are externally perceivable and rely on (multi-)modal sensorimotor experience (Gainotti et al., 2009; Hoffman, 2016; Paivio, 1986). To substantiate the assumed experiential grounding, it is necessary to show a (causal) involvement of experience in the acquisition, representation and processing of word meaning. This has been successfully shown in the action domain: functional magnetic resonance imaging ([fMRI]; Desai et al., 2009; Hauk et al., 2004; Kiefer & Harpaintner, 2020) and transient lesion studies (Pulvermüller et al., 2005) revealed that sensorimotor areas are (causally) involved in processing action semantics. Training studies showed that controlled motor experience increased the recruitment of sensorimotor areas during semantic processing (Bechtold, Ghio, et al., 2019b) and behaviourally facilitated it (Locatelli et al., 2012).

In contrast to concrete concepts, abstract concepts, like *freedom* or the German *schadenfreude* (i.e., a mean pleasure about the misfortune of someone else), lack a physical

referent. Therefore, their grounding should not (predominantly) rely on sensorimotor experiences (Borghi et al., 2017; Pecher & Zeelenberg, 2018). Based on the fact that we often experience abstract words in a verbal or written context (Borghi et al., 2018; Della Rosa et al., 2010), the importance of linguistic experience for abstract concepts is widely recognized (Borghi et al., 2019; Recchia & Jones, 2012; Scorolli et al., 2011). Additionally, emotional information contributes to the acquisition and representation of abstract concepts (Borghi et al., 2017; Vigliocco et al., 2014) and it facilitates behavioural performance through neural grounding in an emotion-related brain network (for a recent review, see Conca et al., 2021). Regarding the acquisition of novel concepts, richer linguistic information (in the form of a higher contextual diversity) led to a deeper encoding (Johns et al., 2015) and emotional information led to a better learning performance specifically for abstract but not concrete words (Ferré et al., 2015). Further, the representation of known abstract words has been shown to be specifically enriched by linguistic and emotional features produced in a *feature production task* ([FPT]; Harpaintner et al., 2018). Based on psycholinguistic ratings, emotional information has been shown to be specifically relevant for abstract words (Ghio et al., 2013; Troche et al., 2014). Finally, assumed richer lexical associations (Barber et al., 2013) and a richer linguistic context with many semantic neighbors (Recchia & Jones, 2012) as well as emotional valence (Kousta et al., 2009; Kousta et al., 2011; Pauligk et al., 2019) facilitated processing in a lexical decision task (LDT) especially for abstract vs. concrete words. In summary, these findings deliver first evidence that linguistic and emotional experience are at least indirectly involved in grounding abstract word meaning.

By now, more direct evidence for a role of linguistic or emotional experience in grounding abstract concepts is limited. One way to test whether experiential grounding causes differences in conceptual representation and processing are training paradigms, which induce novel concepts based on controlled experience. While in the concrete domain, training can incorporate, e.g., visual (Bechtold, Ghio, & Bellebaum, 2018) and motoric (Bechtold, Ghio, et

al., 2019a; Bechtold, Ghio, Lange, et al., 2018) experience, training paradigms inducing novel abstract concepts have to rely on linguistic information. Concerning the role of emotionality, two training studies found a learning and processing advantage of (positive) emotional valence in the concrete domain based on a training with pictures of novel objects (Frances et al., 2020) or with novel words substituting concrete concepts in linguistic contexts (Sneffjella et al., 2020). To our knowledge, only three studies induced a novel (i.e., unknown) meaning for novel concrete and abstract words in purely linguistic training paradigms (Kurmakova et al., 2021; Mkrtychian et al., 2021; Palmer et al., 2013). Palmer et al. (2013) found a general learning and processing advantage for novel concrete over abstract words in a semantic categorisation as well as a lexical decision task after only one training session pairing unknown, rare English words with their definitions. In contrast, Kurmakova et al. (2021) and Mkrtychian et al. (2021) found a higher free recall accuracy and shorter LDT reaction times for novel abstract than concrete words after one training session with contextual learning from five-sentence short stories. Moreover, Kurmakova et al. found that stimulating core language areas with transcranial direct current specifically supports storing abstract knowledge. These studies, however, focussed on newly built memory traces and the concrete-abstract distinction on a more general level, disregarding the emotional content of abstract words. Another training study combined linguistic, social and pictorial experience and showed that children aged 8-9 years learned previously unknown valenced abstract words better than neutral words (Ponari et al., 2020).

Notably, in the previously discussed research, emotional experience was restricted to potential implicit internal simulations during the conceptual processing of emotional words (Barsalou, 2008). To truly induce emotional experience, however, it possibly takes additional explicit *mental imagery*. Imagery is a mechanism, which allows us to experience a concept without any perceptual information (Richardson, 1969). Comparable to actually perceiving emotional stimuli (e.g., angry faces), the instructed imagery of emotions (e.g., *Imagine feeling*

excited) modulated behavioural (Lewis et al., 2013), somato-visceral (Lang et al., 1980; Vrana et al., 1986), and electrophysiological responses (Suess & Abdel Rahman, 2015). Holmes et al. (2008) argued that imagery plays a causal role as an amplifier of emotional experience. The underlying process might be an explicit simulation of sensational states (Kosslyn et al., 2001; Lewis et al., 2013) and/or be related to *interoception*, which has also been shown to play a role especially for abstract emotional concepts (Connell et al., 2018; Craig, 2003). Mental imagery amplified emotional processing compared to linguistic presentation of the same stimuli (Holmes & Mathews, 2010), which could be further increased by the vividness of imagery (O'Donnell et al., 2018).

Up to now it remains unclear, how controlled emotional vs. neutral linguistic stimuli influence the acquisition, representation and processing of abstract concepts in line with fundamental grounded mechanisms. Therefore, we developed a linguistic training paradigm to induce novel abstract concepts over the course of five training sessions. The first goal was to provide evidence for a causal role of laboratory-controlled emotional information in supporting learning, enriching representation and facilitating processing of abstract concepts. We therefore familiarized our participants with 30 novel abstract concepts, 15 neutral and 15 emotional. We presented the novel concepts' names (pseudowords with German phonology, e.g., *Preier*) together with written definitions (e.g., *When you pretend to be disinterested, but actually want something.*) and example situations, in which the concepts could occur (e.g., *A couple of colleagues are sharing a cake in the kitchen. You hope to be offered a piece, but you don't want to seem greedy. Therefore, you pretend that you happen to have something to do in the kitchen.*). To assess learning performance, we included a forced-choice semantic judgment task ([SJT]; i.e., select the correct concept definition from two presented definitions) during training and recognition accuracy in an LDT after training. To investigate the representational content of the novel concepts, we included a free FPT after training. To measure processing performance, we examined lexical decision speed. Our second goal was to find out whether

explicit mental imagery amplifies the effects of emotional experience. Therefore, half of the participants mentally imagined the example situations while the other half lexically rephrased the situations gaining deeper emotional vs. lexico-semantic experience, respectively. We assessed the vividness of the participants' emotional imagery as the inter-individual differences in imagery vividness can affect processing (Blackwell, 2020).

As a necessary premise, we expected that our participants would acquire novel abstract concepts based on the linguistic experience during the training, which should become obvious in well above chance-level accuracy scores for both, the SJT and LDT. Further, we expected the induced emotional experience to support learning, enrich the novel conceptual representations and facilitate their processing, which should result in higher SJT and LDT accuracy, more emotional features generated in the FPT and shorter LDT reaction times for emotional compared to neutral novel concepts, respectively. Finally, we hypothesized that emotional concepts should additionally profit from imagery-amplified emotional experience. Moreover, we expected that effects of the imagery vs. rephrasing training task might vary with the participants' vividness of emotional imagery, with a more vivid imagery amplifying the effects of emotional experience.

Method

Participants

We estimated a required sample size of 30 participants for each of the two experimental groups based on novel object training studies (21 to 24 per group: Bechtold, Bellebaum, et al., 2019; Bechtold, Ghio, & Bellebaum, 2018; Bechtold, Ghio, Lange, et al., 2018; Kiefer et al., 2007) and linguistic training studies (15 to 45 per group: Borovsky et al., 2012; Borovsky et al., 2010; Frishkoff et al., 2010; Günther et al., 2020). As, due to the length of the training phase, we expected a high number of drop-outs and incomplete data sets, we aimed to acquire 40 participants per group. In total, 83 volunteers participated in the study. We excluded nine participants who did not complete the trainings, three participants who were not native

speakers, two who reported a history of psychiatric disease and another two who reported impacted vision and difficulties in reading the text on screen. Further, one participant was excluded for completing the posttest four days after the last training, which exceeded the required zero to two days.

The remaining 66 participants were native German speakers, had normal or corrected-to-normal vision, no psychiatric or neurological diseases, no dyslexia and received at least secondary education ($n = 2$) or were students with at least university entrance degree ($n = 64$). Participants were randomly assigned to one of two groups that differed in the task version, imagery or rephrasing. The final imagery task sample consisted of 32 participants (female: 26) and the rephrasing task sample of 34 participants (female: 26). Independent samples t -tests showed that there was no significant difference in age between participants, who did the rephrasing ($M = 22.9$ years, $SD = 4.6$ years) and the imagery task ($M = 24.2$ years, $SD = 5.5$ years), $t(64) = 1.00$, $p = .322$.

We measured empathy scores as a potential confounding variable with the German version of the Interpersonal Reactivity Index (Saarbrücker Personality Questionnaire [SPQ]; Paulus, 2009). Empathy scores (including the subscales *Perspective Taking*, *Fantasy* and *Empathic Concern*) did not differ between the rephrasing ($M = 47.0$ points, $SD = 4.6$ points) and the imagery group ($M = 47.5$ points, $SD = 6.0$ points), $t(64) = 0.38$, $p = .703$. Further, there was no significant difference in the posttest regarding the vividness of emotional imagery (measured with the Vividness of Emotional Imagery Questionnaire [VEIQ]; for details, see *Procedure* section) between the participants, who did the imagery ($M = 43.7$ points, $SD = 5.7$ points) and the rephrasing task ($M = 43.5$ points, $SD = 6.8$ points), $t(64) = 0.16$, $p = .873$. Within the imagery group, a dependent sample t -test revealed no difference between VEIQ scores between pre- ($M = 43.8$ points, $SD = 6.3$ points) and posttest, $t(31) = -0.12$, $p = .909$. All participants gave written informed consent prior to participation and

received monetary compensation or course credit. The study procedure was in line with the declaration of Helsinki and received approval by the local ethics committee.

Stimuli

Novel concepts

An informal internet research (including among others the search terms ‘unknown words’, ‘foreign words’ and ‘untranslatable words’ on the platforms Google and Pinterest) yielded an initial pool of 150 novel concepts imported from other languages, which were non-existent in the German lexicon. We excluded synonymous concepts, concrete concepts, concepts that were ambiguous in valence and those that were similar to the meaning of an existent German word. This led to a reduced stimulus pool of 59 concepts. We created an emotional (e.g., *the feeling that you could fall in love with the person you just met*) and a neutral (e.g., *the consideration that you will see again the person that you just met*) definition for each concept, describing each concept as a noun and avoiding sentential negations in the definitions. We collected psycholinguistic ratings on these 2×59 definitions, presented in randomized order, from five independent raters, who did not participate in the final experiment. Ratings on familiarity, imageability, arousal, valence, and association with social interaction were collected on Likert scales. The valence scale ranged from -3 (*very negative*) to 3 (*very positive*). The social interaction scale ranged from 1 (*not associated*), over 2 (*possibly but not necessarily associated*) to 3 (*necessarily associated*). All other scales ranged from 1 (*very low*) to 7 (*very high*). All data sets were complete (no missing data). We calculated Cronbach’s alpha (Cronbach, 1951) per rating scale following the procedure of Lynott et al. (2019). For all scales, α values were $\geq .82$, reflecting a very good agreement between raters. We thus calculated the mean rating score for each definition on each scale.

We selected the final 30 concepts for the experiment to contain 15 positively and 15 negatively valenced concepts, which did not differ in arousal. We further balanced their association with social interaction (associated or not associated, discarding ambiguous cases).

We then matched neutral and emotional definitions for familiarity, $t(29) = -0.62$, $p = .540$, and imageability, $t(29) = 0.36$, $p = .725$. Finally, the neutral and emotional definitions did not differ significantly in word count, social interaction, and signed valence, all $ps \geq .476$. Signed valence allows us to rule out a different negative or positive bias for emotional and neutral definitions (Vinson et al., 2013). Ratings confirmed significant differences between the neutral and emotional definitions in arousal, $t(29) = 6.45$, $p < .001$, and absolute valence values, $t(29) = 7.27$, $p < .001$. Absolute valence is a measure reflecting the overall emotionality, irrespective of whether it is positive or negative, shown to be the best predictor of LDT reaction times (Vinson et al., 2013). For descriptive statistics, see Table 1 and for a full list of the emotional and neutral definitions (in German, including English translations) of the final 30 concepts, see Table A1 in Appendix A in the supplementary material (<https://osf.io/gjc8p/>).

Table 1

Descriptive statistics for the psycholinguistic variables of the definitions of the final 30 concepts

Variable	Emotional		Neutral	
	<i>M</i>	<i>SD</i>	<i>M</i>	<i>SD</i>
Word count	11.67	2.80	11.60	2.57
Familiarity	5.18	1.10	5.27	1.04
Imageability	4.35	0.86	4.29	1.20
Social Interaction	2.13	0.73	2.09	0.73
Signed Valence	0.37	1.90	0.33	1.00
Valence	1.81	0.60	0.82	0.64
Arousal	4.58	1.25	3.37	1.01

Note. Means (*M*) and standard deviations (*SD*) of novel concept ratings.

For each concept, we created five exemplary situations in German, each emotionally (e.g., *On a train ride you meet a person who amazes you from the very beginning. You feel like you just met your soulmate.*) and neutrally formulated (e.g., *On a train ride you talk to another person. You find out that you are studying at the same faculty so you will probably meet again.*). We presented a different situation per word in each training session, aiming at

enhancing the generalizability, contextual diversity, and comprehensibility of the concepts. We addressed participants directly with the second person singular as it creates a referential link to the addressee, favouring simulation (Gast et al., 2015). All situations consisted of two to four affirmatively formulated sentences. We tried to keep neutral and emotional definitions as parallel as possible by selectively exchanging emotional and neutral words. However, sometimes we had to describe differing situations, which we matched in word count. A paired sample *t*-test revealed no difference in word count between neutral ($M = 26.2$ words, $SD = 4.3$ words) and emotional situations ($M = 26.2$ words, $SD = 4.5$ words), $t(149) = 0.00$, $p > .999$. The full list of neutral and emotional situations (in German, including English translations) is provided in Tables A2 to A6 in Appendix A in the supplementary material (<https://osf.io/gjc8p/>).

We used the software *Wuggy* (Keuleers & Brysbaert, 2010) with the German language module to generate the 30 pseudowords, which served as names for the novel concepts to be presented in the training (referred to as novel words). As input, we used the 12 abstract emotion nouns from the VEIQ and 18 emotional nouns occurring in the emotional definitions of the concepts as input into *Wuggy*. The pseudowords were one to three syllables and three to ten letters long ($M = 7.4$ letters, $SD = 2.4$ letters). We created five pseudowords per input word and selected the first one that did not contain an existent German word or a recognizable German word root as concepts' names. Each name was assigned to one of the concepts randomly. Notably, the emotional and neutral version of the concept received the same name, as they were never seen both by the same participant (see below). A full list of the novel concept names can be found in Table A1 in Appendix A in the supplementary material (<https://osf.io/gjc8p/>).

In order to create two parallel versions of the stimuli controlling for any potential systematic differences, concepts were divided into two parallel sets (A and B). Each set included 15 emotional and 15 neutral concepts, balanced in valence and social interaction.

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Each concept was included with its neutral definition in one set and with its emotional definition in the other set. Paired samples *t*-tests revealed neither a significant difference in word count of the definitions between Set A ($M = 11.7$ words, $SD = 2.6$ words) and Set B ($M = 11.6$ words, $SD = 2.8$ words), $t(29) = 0.34$, $p = .738$, nor of the word count in the situations between Set A ($M = 26.2$ words, $SD = 4.5$ words) and Set B ($M = 26.2$ words, $SD = 4.3$ words), $t(149) = 0.00$, $p > .999$. The participants were randomly assigned to see either Set A ($n = 33$) or Set B ($n = 33$).

Real words

For detailed stimulus selection of the 30 words displayed in the real word LDT, which served as reaction time validation by comparing known and pseudowords, see Appendix B in the supplementary material. We used these 30 real words to generate 90 pseudowords to be displayed in both LDT blocks. They were one to three syllables and three to ten letters long ($M = 7.5$ letters, $SD = 2.2$ letters). To make sure word length differences between words and pseudowords did not affect response latencies in the LDT (Whaley, 1978), we conducted independent samples *t*-tests, which revealed neither a significant difference of word length between pseudowords and novel words $t(118) = 0.07$, $p = .944$, nor between pseudowords and real words, $t(39.48) = 1.17$, $p = .249$.

Procedure

General procedure

Figure 1 summarizes the procedure of this study. Each participant completed a pretest, followed by five training sessions, and a subsequent posttest, which all took place online. The pretest could be completed on the same day as the first training. The intervals between trainings had to be at least one, but maximum five days long. The mean interval between training sessions was 1.4 days ($SD = 0.6$ days). The posttest could be completed on the same day as the last training, but not more than two days apart. The mean interval between the last training and the posttest was 0.1 days ($SD = 0.4$ days). On average, participants had 5.9 days

($SD = 2.4$ days, range: 4 to 13 days) between the pretest and the posttest. Independent samples t -tests revealed neither a significant difference in the interval between all seven sessions of the study between the imagery ($M = 5.6$ days, $SD = 2.3$ days) and the rephrasing training task ($M = 6.2$ days, $SD = 2.4$ days), $t(64) = -1.11$, $p = .272$, nor in the interval between the last training session and the posttest between the imagery ($M = 0.1$ days, $SD = 0.3$ days) and the rephrasing task ($M = 0.1$ days, $SD = 0.4$ days), $t(64) = 0.42$, $p = .679$.

The study was programmed in Psychopy (version 3.0, www.psychopy.org; Peirce et al., 2019) and executed on the Pavlovia online platform (www.pavlovia.org). The whole study took 4 to 5 hours. Participants received course credits or 20 € as compensation.

Pretest procedure

In the pretest, we collected demographical data and participants completed the SPQ (Paulus, 2009). Further, we created a VEIQ consisting of twelve items involving known emotions (e.g., *anger*; see Appendix C in the supplementary material [<https://osf.io/gjc8p/>]). We imported the instructions and the five items from the emotional feeling subscale of the *Plymouth Sensory Imagery Questionnaire* (Andrade et al., 2014) and added more words to reach the same amount of items as in the *Vividness of Visual Imagery Questionnaire II* (Marks, 1995). Participants were asked to imagine themselves experiencing the emotion and subsequently rate how strongly they felt it on a 5-point Likert scale reaching from 1 (*I do not feel the emotion, I only think of it*) to 5 (*I feel the emotion very strongly*). Only the participants, who did the imagery task, completed the VEIQ in the pretest as we did not want to prime mental imagery as an internal learning strategy for the rephrasing task. In the last part of the pretest, all participants read the definitions of the concepts and rated how familiar they were with the concepts on a 5-point Likert scale ranging from 1 (*not familiar at all*) to 5 (*very familiar*). Further, they estimated how often they had experienced the concept in the past four weeks on a 5-point Likert scale ranging from 1 (*never*) to 5 (*several times a day*). The pretest took about 10 to 20 minutes.

Figure 1

Experimental procedure

Note. VEIQ = vividness of emotional imagery questionnaire, IRI = interpersonal reactivity index.

^aAssessed only in the posttest for the rephrasing group

Training procedure

Before the first training session, participants saw an example of the sequence of events during the training containing a novel concept, which did not occur in the actual experiment. In all training sessions, all concepts were presented once in randomized order. All trials started with the presentation of a novel word and its definition. On average, participants remained on this screen for 8.01 s ($SD = 14.52$ s) until they pressed the button to proceed to the next screen, which displayed the novel word and one exemplary situation. On average, they remained on this screen for 6.63 s ($SD = 10.24$ s) until they proceeded to the next screen. Subsequently, participants were instructed to imagine how they would feel in the situation (imagery training task) or to rephrase the situation mentally (rephrasing training task). Earliest after 10 s, participants were allowed to move on to the next concept. Time was limited to a maximum of 30 s. On average, participants performed the task for 13.26 s ($SD = 2.09$ s, range: 10.9 s to 22.0 s). A linear mixed effects (LME) analysis revealed a significant effect of Emotionality, $p = .010$, with longer duration for emotional ($M = 13.29$ s, $SD = 3.81$ s) than neutral concepts ($M = 13.11$ s, $SD = 3.71$ s). For detailed description of the analysis, see Appendix D in the supplementary material (<https://osf.io/gjc8p/>). During the task, the novel word and the situation stayed on screen. Finally, a blank screen was presented for 1000 ms.

In the first and last training sessions, participants additionally rated the emotionality of the concept after the presentation of the definition on a 7-point Likert scale ranging from - - - to + + +, where - meant a negative valence, + a positive valence and the number of -/+ reflected the arousal. For economic reasons we did not assess valence and arousal separately. The signed values obtained on this scale represent valence, the absolute values represent emotionality (0 = neutral, > 0 = emotional).

In the first and last training session, after completing their task, participants additionally rated how difficult it was to conduct the imagery or rephrasing on a 5-point Likert scale

ranging from 1 (*very easy*) to 5 (*very difficult*). For detailed analysis of these ratings see data analysis section.

After the second and forth training session, we assessed the participants' learning performance with a forced-choice SJT. We displayed a novel word with one correct and one incorrect definition presented next to each other on the screen and participants were asked to choose the correct definition by pressing the 'X' (left) or 'M' (right) key. As distractor definitions, we randomly assigned (once for the second and once for the forth training) one of the remaining 29 definitions from the given experiment version, and kept them constant across participants. Participants received feedback immediately after the choice. If the answer was wrong, the correct definition was displayed. We used this task to measure the learning progress and to assess whether participants linked the concepts to the novel words. Further, testing with feedback within the training should enhance learning (Palmer et al., 2013; Roediger & Karpicke, 2006). In total, the five training sessions took about 2.5 to 3 hours.

Posttest procedure

After seeing an example of an LDT trial and reading the instructions, participants completed the novel word LDT. Each trial started with the central presentation of a fixation cross for 500 ms. Afterwards, the target appeared at the same location, which was either an unknown pseudoword or a novel word from the training. The answer options 'pseudo (X)' on the left side and 'word (M)' on the right side were displayed below the target. Participants made their choice by pressing the left key ('X') if they thought it was a pseudoword or the right key ('M') if they thought it was a novel word. They were instructed to leave their right and left index fingers on the respective key the entire time and to answer as fast and accurately as possible. If they did not give an answer within 4000 ms, the next trial started automatically. Each of the 30 novel words was presented three times and each of the 90 pseudowords was presented once, resulting in 180 novel word LDT trials. Every 30 trials, participants had the possibility to take a break of a self-administered duration. Subsequently,

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the participants completed the real word LDT. The procedure was the same as described above. We presented 30 real words, each repeated three times, and 90 pseudowords, resulting in 180 real word LDT trials.

Afterwards, participants completed the FPT, in which they were instructed to write down all features they associated with the concepts. Instructions specified that features could be internally perceptible (bodily sensations), externally perceptible (optics, haptics, sounds, taste), functional associations (how, where, when used by whom), or non-physical (feelings, thoughts, opinions) and that there were no right or wrong answers. We provided two examples of concepts, which were not used in the training, with example features before the actual task started. Each novel word with its definition was displayed at the top of the screen. This aimed to reduce (uncontrolled) uncertainty of the participants regarding the concepts' meaning and, at the same time, keep them from simply repeating words from the (at this point familiar) concept definitions. Participants used their keyboards to enter their answers, which were displayed in the centre of the screen. They had a maximum of 90 s but could move on to the next concept earlier. On average, participants worked on the task for 49.63 s ($SD = 20.2$ s, range: 15.5 s - 84.7 s). To make sure that participants noticed the beginning of the next trial, there was a break of 2000 ms before the next trial. A short version of the instructions was presented above the novel word the entire time.

After completing the FPT, participants rated the familiarity of concepts as well as how often they experienced the concept in the past four weeks, as for the pretest. Subsequently, all participants completed the VEIQ. At last, we asked participants to freely report any internal learning strategies and the utilized technical equipment. The posttest took about 90 minutes.

Data Analysis

We analysed the data using R Studio (version 1.03.1093). We conducted (G)LMEs as they allow to control for variance introduced by stimuli and participants (Baayen et al., 2008; Judd et al., 2012). For the generalized linear mixed effects (GLME) analyses of binary single-

trial accuracy data, we used the afex package (version 0.27-2; Singmann et al., 2017). Degrees of freedom and significance were estimated based on the likelihood-ratio test method based on type III sums of squares. Interactions were resolved using the R package emmeans (version 1.6.1; Lenth, 2021). For linear mixed effects (LME) analyses of LDT reaction times and number of features produced, we used the R packages lme4 (version 1.1-21; Bates et al., 2015) and lmerTest (version 3.1-3; Kuznetsova et al., 2017), which uses Satterthwaite's method to estimate degrees of freedom and significance (Luke, 2016). Interactions were resolved using the R package interactions (version 1.1.3; Lang, 2019). For each LME analysis, we performed an outlier detection based on Cook's distance (Cook, 1977) using the R package influence.ME (version 0.9-9; Nieuwenhuis et al., 2012). Values ranged from < 0.01 to 0.43 over all estimated models ($M = 0.03$, $SD = 0.05$). Thus, no subject's Cook's distance exceeded the cut-off of 1 originally suggested by Cook (1977). Based on simulations, Jayakumar and Sulthan (2014) would suggest more conservative cut-off values of ~ 0.13 to reflect a significant influence for our sample size and number of included predictors. We made sure that the inferential pattern obtained from the full sample prove robust against the exclusion of participants exceeding this cut-off ($n = 2$ for the LDT reaction time analysis and $n = 1$ for the FPT analysis).

For the LDT analyses, we excluded one participant, who consistently pressed the same button in the real word LDT resulting in a 50 % accuracy, for which we assumed a low compliance and motivation. Further, we excluded five participants, who reached an accuracy ($\leq 56.7\%$) more than 2 SD below the sample's mean accuracy in the SJT after the fourth training ($M = 89.5\%$, $SD = 14.3\%$) and one more participant, whose accuracy (15.6 %) deviated more than 2 SD from the sample's mean accuracy in the novel word LDT ($M = 94.2\%$, $SD = 13.2\%$). Thus, for the analysis on LDT accuracy, 59 participants were included (rephrasing task: 32, imagery task: 27). For LDT reaction time analysis, we logarithmically transformed reaction times (in s; $[RT]_{\log}$) to reduce right-skewed deviation from the normal

distribution (Box & Cox, 1964; Kousta et al., 2011; Vinson et al., 2013). Additionally, we excluded one more participant from the rephrasing group, whose mean LDT reaction time (1,381 ms, $SD = 382$ ms) deviated more than 2 SD from the sample's mean ($M = 705$ ms, $SD = 301$ ms). Further, we only included trials with correct answers (96.9 %). We refrained from further a priori data trimming, as no reactions exceeded the range of reactions between 5 ms and 5 s as suggested by Baayen and Milin (2010). We then applied the outlier criterion based on model criticism by excluding trials with standardized residuals higher than 2.5 or lower than -2.5 (3.0 %; Baayen & Milin, 2010). We reduced a right-skewed deviation from normal distribution observable in QQ-plots by taking the $RT_{\log}$ (Baayen et al., 2008; Box & Cox, 1964; Trippas et al., 2016) in order to perform the LME analyses, which are robust to small violations of distributional assumptions (Schielzeth et al., 2020). R scripts, csv files and outputs are provided in the supplementary material (<https://osf.io/gjc8p/>).

Validation Analyses

Before analyzing the data from the LDT and FPT, we extensively validated our manipulation of the novel concepts' emotionality. An LME analysis on absolute emotionality ratings revealed a significant effect of Emotionality and a significant interaction of Emotionality and Time Point, both $p \leq .001$. At both time points, emotional concepts were rated as being significantly more emotional than neutral concepts, even more so after the last than the first training. We additionally checked for potentially confounding familiarity differences. Familiarity increased from pre to posttest, $p = .005$. Further, participants in the imagery task rated emotional concepts as more familiar than neutral concepts, $p = .001$, which was not significant in the rephrasing task, $p = .575$. Additionally, we controlled task comparability by analyzing subjective difficulty ratings of both tasks. An LME analysis on difficulty ratings revealed an interaction of Training Task and Time Point, $p = .044$, in which difficulty increased for the imagery but decreased for the rephrasing task from the first to the fifth training. There were no significant differences between groups at either time point, both

$ps \geq .323$. Finally, we controlled the interpretability of LDT reaction time data acquired online by replicating the lexicality effect in real word LDTs (James, 1975). The LME analysis on real word LDT reaction times revealed a significant Lexicality effect, $p < .001$. For detailed description of all validation analyses, see Appendix E in the supplementary material (<https://osf.io/gjc8p/>).

Analyses of Word Acquisition

SJT Accuracy. To investigate the successful induction of novel concepts by the training procedure, we investigated the SJT accuracy with a binomial GLME analysis including the categorical fixed-effects factors Training Task (rephrasing [-0.5], imagery [0.5]), Emotionality (neutral [-0.5], emotional [0.5]), and Time Point (second training [-0.5], fourth training [0.5]) and the mean-centred, continuous fixed-effect factor VEIQ Scores as well as their interactions as predictors. As random-effect factors we included the slope and intercept for each Subject and Novel Word. We further included random slopes of Emotionality and Time Point and their interaction per Subject. In total, 3,960 data points were included.

LDT Accuracy. We conducted a binomial GLME analysis on LDT accuracy. We defined a model with the categorical fixed-effect predictors Training Task (rephrasing [-0.5], imagery [0.5]), Emotionality (neutral [-0.5], emotional [0.5]), Lexicality (pseudowords [-0.5], novel words [0.5]) and the mean-centred, continuous fixed-effect factor VEIQ Scores as well as their interactions as predictors. We assigned the pseudowords to the same Emotionality level as their corresponding novel word (i.e., the one generated from the same real word in the pseudoword generator). As random-effect factors we included the slope and intercept for Subject and Novel Word as well as the random slopes of Emotionality and Lexicality (but not their interaction as it produced a singular fit) per Subject. In total, 10,620 data points were included.

Analyses of Representational Content

The features generated by participants were qualitatively categorized using a procedure adapted from Barsalou and Wiemer-Hastings (2005). Three independent raters rated the association of the features with five different categories: emotion, cognition, social interaction, interoception, and external perception. Answers were given on 7-point Likert scales ranging from 1 (*low*) to 7 (*high*). All data sets were complete (no missing data). For all scales, Cronbach's (1951) α values were $\geq .99$, reflecting a very good agreement between raters (Cronbach, 1951; Lynott et al., 2019). We thus calculated the mean rating score for each definition on each scale. We then identified the scale, on which the word received the maximum mean rating. If this maximum mean rating was ≥ 3 , the feature was assigned to the respective category. If the maximum was < 3 , the feature was not assigned to a category and excluded from further analysis (10.0 % of features). If the maximum mean rating was ≥ 3 and identical for two or more scales, the feature was assigned to all the corresponding categories (8.3 % of features).

To examine the novel concepts' semantic richness in form of the quantity of generated features, we conducted a GLME analysis on the number of features created by each participant for each of the novel words with the Poisson distribution as the assumed probability distribution (suitable for count data, see Winter & Bürkner, 2021). We defined a model with the categorical fixed-effect predictors Training Task (rephrasing [-0.5], imagery [0.5]), Emotionality (neutral [-0.5], emotional [0.5]), Category (deviation coding; emotion vs. cognition vs. social interaction vs. interoception vs. external perception) and the mean-centred, continuous fixed-effect factor VEIQ Scores as well as their interactions as predictors. As random-effect factors we included the slope and intercept for each Subject and Novel Word. We further included random slopes of Emotionality and Category per subject. In total, 5,375 data points were included.

Analysis of Lexico-Semantic Processing

We conducted an LME analysis on the single-trial $RT_{\log}$ data of the LDT. We defined a model with the categorical fixed-effect predictors Training Task (rephrasing [-0.5], imagery [0.5]), Emotionality (neutral [-0.5], emotional [0.5]), and the mean-centred, continuous fixed-effect factors Semantic Richness (the number of features created in the FPT), and VEIQ Scores as well as their interactions as predictors. As random-effect factors we included the slope and intercept for each Subject and Novel Word. We did not include random slopes of Emotionality per subjects as this led to a singular fit. In total, 4,811 data points were included.

Results

We conducted (G)LME analyses targeted to test our hypotheses regarding abstract word acquisition, representational content and lexico-semantic processing after training, respectively. To enhance readability, we only report significant effects ($p < .05$) and resolutions of highest order interactions in the text.

Word Acquisition

SJT Accuracy

One sample t -tests showed that SJT accuracy was significantly above 50% chance level after the second ($M = 81.0\%$, $SD = 16.0\%$), $t(65) = 15.75$, $p < .001$, and fourth training ($M = 89.5\%$, $SD = 30.7\%$), $t(65) = 22.27$, $p < .001$. We conducted a GLME analysis on the SJT accuracy including the factors Training Task (imagery [$n = 32$] vs. rephrasing [$n = 34$]), Time Point (after the second vs. fourth training), Emotionality (emotional vs. neutral words), and the mean-centred VEIQ Scores. For β -estimates and effect-specific z -tests of the GLME analysis of SJT accuracy see Table F1A, for descriptive statistics see Table F2 in Appendix F.

Results revealed significant effects of Training Task, $p = .006$, Time Point, $p < .001$, as well as their interaction, $p = .005$. Post-hoc simple slope analyses of the Training Task $\times$ Time Point interaction revealed that after the second training, the accuracy did not differ between

the rephrasing ($M = 83.7\%$, $SD = 36.9\%$) and the imagery group ($M = 78.0\%$, $SD = 41.4\%$), $p = .138$. After the fourth training, the rephrasing task ($M = 93.3\%$, $SD = 25.0\%$) led to a significantly higher accuracy compared to the imagery task ($M = 85.4\%$, $SD = 35.3\%$), $p = .004$. The Training Task $\times$ Emotionality interaction was significant as well, $p = .017$. Post-hoc simple slope analyses revealed that for neutral concepts, the rephrasing task led to a higher accuracy ($M = 89.4\%$, $SD = 30.8\%$) than the imagery task ($M = 80.3\%$, $SD = 39.7\%$), $p = .002$. For emotional concepts, accuracy did not differ significantly between the rephrasing ($M = 87.7\%$, $SD = 32.9\%$) and the imagery task ($M = 83.1\%$, $SD = 37.5\%$), $p = .116$. The Training Task $\times$ VEIQ Scores interaction was significant as well, $p = .024$ (see Figure 2). Post-hoc simple slope analyses revealed that for the rephrasing task, higher VEIQ scores led to a higher accuracy, $p = .021$, while the VEIQ scores had no significant effect on accuracy for the imagery task, $p = .768$. All other effects were not significant, all $ps \geq .204$. Taken together, SJT accuracy was significantly higher for the rephrasing than the imagery task after the fourth but not yet after the second training session and when judging neutral but not emotional words. Further, after the rephrasing but not after the imagery task, a higher VEIQ significantly increased SJT accuracy.

Figure 2

Descriptive pattern of the interaction effects of Training Task and A. Time Point, B.

Emotionality and C. VEIQ Score on the accuracy in the semantic judgment task

Note. Mean accuracy in % for the imagery ($n = 32$) and the rephrasing group ($n = 34$). VEIQ = vividness of emotional imagery questionnaire. Error bars represent $\pm 1 SE$ (A and B), semi-transparent ribbons show 90% confidence intervals (C).

LDT Accuracy

The overall accuracy in the LDT with novel words ($M = 96.9\%$, $SD = 5.2\%$) did not differ significantly from the accuracy in a control LDT with real words ($M = 97.7\%$, $SD = 2.0\%$), as shown by a dependent samples t -test, $t(58) = -1.34$, $p = .184$. We conducted a GLME analysis on accuracy in the novel word LDT including the factors Training Task (imagery [$n = 27$] vs. rephrasing [$n = 32$]), Emotionality (emotional vs. neutral words), Lexicality (pseudowords vs. novel words) and mean-centred VEIQ Scores. We assigned the pseudowords to the same Emotionality level as their corresponding novel word (i.e., the one generated from the same real word in the pseudoword generator). For β -estimates and effect-specific z -tests see Table F1B, for descriptive statistics see Table F3 in Appendix F. Results revealed a significant effect of Lexicality, $p = .002$. The accuracy was higher for pseudowords

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($M = 98.5\%$, $SD = 12.1\%$) than for novel words ($M = 95.3\%$, $SD = 21.2\%$). All other effects were not significant, all $ps \geq .120$. Taken together, the LDT accuracy for the novel words reached a comparable level to real words, and pseudowords were recognized with a higher accuracy than the novel words.

Representational Content

We conducted a GLME analysis on the number of features produced per novel concept per participant in the FPT. The analysis included the factors Training Task (imagery [$n = 32$] vs. rephrasing [$n = 34$]), Emotionality (emotional vs. neutral words), Category (emotion vs. cognition vs. social interaction vs. interoception vs. external perception), and mean-centred VEIQ Scores. For β -estimates and effect-specific t -tests, see Table F4, for descriptive statistics, see Table F5 in Appendix F.

Results revealed a significant main effect of Category, $p < .001$, and a significant Category $\times$ Emotionality interaction, $p < .001$. Post-hoc simple slope analyses revealed that for emotional compared to neutral novel concepts more emotion features, $p < .001$, but less cognition features, $p < .004$, were produced (see Figure 3A). There was no significant difference between neutral and emotional novel concepts for features in the other categories, $p \geq .593$. Additionally, the Category $\times$ VEIQ Scores interaction was significant, $p = .018$. Post-hoc simple slope analyses revealed, only descriptively, participants with higher VEIQ scores created more emotion, cognition and interoception features and less social interaction and external perception features, all $ps \geq .147$ (see Figure 3B). All other effects of the LME analysis on the number of features were not significant, $p \geq .124$. Taken together, participants produced specifically more emotion features for emotional words and relatively more cognition features for neutral words. Further, higher VEIQ scores descriptively enhanced the number of features concerning internal experience (emotion, cognition, interoception).

Figure 3

Descriptive pattern of the interactions of Category and A. Emotionality and B. VEIQ Score on the number of features created in the feature production task.

Note. Mean number of features produced by all participants ($n = 66$). VEIQ = Vividness of Emotional Imagery Questionnaire, COG = cognition features, EMO = emotion features, EXT = external perception features, INT = internal perception features, SOC = social interaction features. VEIQ scores were split into high ($M + 1 SD$) and low ($M - 1 SD$) values. Error bars represent $\pm 1 SE$.

Lexico-semantic processing

We conducted an LME analysis on LDT RT_{log} including the factors Training Task (imagery [$n = 27$] vs. rephrasing [$n = 31$]), Emotionality (emotional vs. neutral words), as well as the mean-centred Semantic Richness (the number of features produced in the FPT) and VEIQ Scores. For β -estimates and effect-specific t -tests, see Table F6 in Appendix F.

The analysis revealed significant interactions of Training Task $\times$ Semantic Richness, $p < .001$, Semantic Richness $\times$ Emotionality $\times$ VEIQ Scores, $p = .040$, as well as Training Task $\times$ Semantic Richness $\times$ Emotionality $\times$ VEIQ Scores, $p = .014$. For the descriptive statistics of the four-way interaction see Figure 4. To resolve this interaction, we split the data set according to the two training tasks and calculated LMEs for each task separately. The

LME analysis for the imagery task revealed a significant Emotionality $\times$ Semantic Richness $\times$ VEIQ Scores interaction, $\beta < 0.01$, $SE < 0.01$, $t(2183.38) = 2.39$, $p = .017$. Post-hoc simple slope analyses revealed that for participants with high VEIQ scores ($> M + 1 SD$) a higher Semantic Richness led to slower reactions to emotional novel words, $p = .010$, while it neither affected reaction times for participants with lower VEIQ scores ($< M - 1 SD$) nor for neutral novel words, all $ps \geq .083$ (see Figure 4, left). In the LME analysis for the rephrasing task, the Emotionality $\times$ Semantic Richness $\times$ VEIQ Scores interaction was not significant, $\beta < 0.01$, $SE < 0.01$, $t(2511.14) = -0.56$, $p = .574$. Notably, within the rephrasing group, the main effect of Semantic Richness was highly significant, $\beta < 0.01$, $SE < 0.01$, $t(2171.07) = -3.37$, $p < .001$, with higher richness leading to faster reaction times in all conditions (see Figure 4, right). Taken together, the complex interaction pattern revealed that higher semantic richness led to slower LDT RT_{log} in response to emotional words for participants with a high VEIQ, who engaged in the imagery task during training. In participants, who engaged in the rephrasing task, higher semantic richness led to faster RT_{log} in all conditions.

Figure 4

Descriptive pattern of the Training Task $\times$ Emotionality $\times$ Semantic Richness $\times$ VEIQ Scores interaction on logarithmically transformed reaction times in the lexical decision task

Note. Mean logarithmically transformed reaction times (RT_{log}) for the imagery group ($n = 27$) and rephrasing group ($n = 31$) for low ($M - 1 SD$) to high ($M + 1 SD$) semantic richness. VEIQ = vividness of emotional imagery questionnaire. Semi-transparent ribbons show 90 % confidence intervals.

Discussion

In this study, we investigated how controlled emotional vs. neutral linguistic experience influences the acquisition, representation and processing of abstract concepts. In five linguistic training sessions, participants learned the names and definitions of neutral and emotional novel abstract concepts and engaged either in mental imagery or in lexical rephrasing of example situations, in which the novel concepts could occur. Our data met the necessary premise of a high semantic judgment and lexical decision accuracy, which showed that participants successfully acquired and recognized the novel concepts. Additional analyses (see Appendix E on <https://osf.io/gjc8p/>) validated the manipulation of the concepts' emotionality, which resulted in distinctive emotionality ratings of emotional vs. neutral concepts before but even more so after training. Regarding the assumed advantageous effects

of concept emotionality, we could confirm our hypothesis of specifically enriched representations: participants produced more emotional features for emotional compared to neutral novel concepts. However, concept emotionality in interaction with emotional imagery did not benefit learning and processing in the expected way. In contrast, after engaging in explicit imagery of emotional words a higher semantic richness even showed detrimental effects on LDT reaction times, selectively for participants with a high vividness of emotional imagery. After engaging in lexico-semantic rephrasing, participants learned especially neutral words better than after imagery, and acquired semantic richness benefitted acquisition and processing of the novel concepts. Importantly, additional analyses (see Appendix D and E on <https://osf.io/gjc8p/>) ruled out a confound of the differences between the imagery and rephrasing task based on difficulty or duration.

Our results clearly show that we successfully induced novel abstract concepts with linguistic experience alone, reaching an LDT accuracy comparable to real words and a well above chance level SJT accuracy. Participants thus not only recognized the novel words as such but also associated them to their conceptual content. An additional analysis of familiarity ratings (see Appendix E on <https://osf.io/gjc8p/>) showed that a higher subjective familiarity mirrored the successful acquisition. Our findings are in line with training studies, which induced novel word meaning based on a single training session with concrete vs. abstract concepts (Kurmakaeva et al., 2021; Mkrtchian et al., 2021; Palmer et al., 2013). We attribute the participant's high learning success partially to a high motivation and compliance of our sample, based on anecdotal feedback of our participants that the study was “fun”. By establishing a causal link to the linguistic experience, our findings further support the notion that linguistic experience is sufficient for acquiring and thus possibly grounding abstract concepts comparably to how sensorimotor experience forms and grounds concrete concepts (Borghi & Zarcone, 2016; Hoffman, 2016).

Beyond the mere linguistic induction of novel concepts, we investigated the effect of emotional experience, in form of the concepts' emotionality and (the vividness of) emotional imagery, on their acquisition, representation and processing. We only found the expected advantageous effect of concept emotionality on representational richness: participants produced specifically more emotional features for emotional compared to neutral novel concepts. Vice versa, they produced relatively more cognitive features for neutral than emotional novel concepts. This result pattern is in line with previous findings that the semantic content of a concept's representation is closely linked to its semantic category (Borghi, 2020; Desai et al., 2018; Ghio et al., 2013; Harpaintner et al., 2018; Villani et al., 2019). Further, the effect of the interindividual vividness of emotional imagery mirrored the effect of concept emotionality descriptively: also here, a specific surplus of emotion features could be observed after emotional experience (in the form of a vivid emotional imagery), however irrespective of whether participants engaged in the imagery vs. rephrasing task during training. In conclusion, our FPT results support the notion that emotional content experienced during training enriched semantic representations of abstract concepts (Kousta et al., 2011; Vigliocco et al., 2014), thereby potentially contributing to their experiential grounding (Barsalou, 2008).

At odds with our hypotheses, we found no significant advantageous effects of concept emotionality or emotional imagery on learning performance measures. Post-hoc model comparisons revealed that Emotionality or its interactions did not explain a significant amount of additional variance in semantic judgment or lexical decision accuracy. In line, the estimated Bayes Factor indicated very strong evidence in favor of an absence of an effect of Emotionality on either learning measure (for details, see Appendix G on <https://osf.io/gjc8p/>). While we found neither detrimental nor facilitative effects on SJT or LDT accuracy by concept emotionality, previous studies consistently reported an advantage for emotional over neutral words (for a recent review, see Conca et al., 2021; Crossfield & Damian, 2021;

Eviatar & Zaidel, 1991; Kousta et al., 2009; Pauligk et al., 2019). Possibly, our results reflect an initial stage of word lexicalization with more effortful processing (Mutter & Hashtroudi, 1987). This subjective effort might have shifted the speed-accuracy trade-off in the LDT (Ratcliff et al., 2004) in favour of a stronger modulation of reaction times than accuracy. Whether the effect of emotionality on LDT accuracy changes along the timeline of a word's consolidation into the mental lexicon has to be further investigated in longitudinal studies.

Further unexpectedly, emotional experience in the form of explicit imagery led to a lower SJT accuracy than lexical rephrasing. This took effect specifically after the fourth but not second training, for neutral but not emotional concepts and for participants with high but not low VEIQ scores. Notably, we did not include a baseline condition without any deep processing task as this would have either led to systematically shorter training trials (e.g., when omitting the interval of the training task) or potential uncontrolled processes (e.g., when including the interval without any task), confounding the baseline and limiting its validity. Thus, any processing disadvantage of imagery can only be interpreted as relative to rephrasing and we assume that both tasks were beneficial to novel concept acquisition.

Regarding the processing of the novel concepts, we found the expected faster reaction times with higher semantic richness consistently in all conditions for the rephrasing group, which is partly in line with previous research (Yap et al., 2015; Yap et al., 2012). However, we did not find the expected processing advantage for emotional over neutral words, even though emotional words were rated as more emotional and more subjectively familiar after training and both dimensions have been shown to speed up lexical decisions (Colombo et al., 2006; Conca et al., 2021). Quite the contrary, for participants, who had performed the imagery task during training and reported a high vividness of emotional imagery higher semantic richness of emotional words led to selectively slower lexical decisions. This was unexpected, as emotionality-based semantic richness has been suggested to facilitate especially abstract word processing (Conca et al.,

2021; Kousta et al., 2011; Newcombe et al., 2012). One possible post-hoc explanation for this discrepancy might be the early stage of consolidation of our novel concepts in comparison to real words. In line with this, an fMRI study showed that additional (non-linguistic) pictorial information led to a weaker lexicalization immediately after training than merely phonologically encoded novel words (Takashima et al., 2014). In our case, the highly salient imagery-enriched emotional information might have had a comparable effect, whereas linguistic semantic richness acquired during lexico-semantic rephrasing benefitted the lexicalization of the novel concepts.

In contrast to our finding, another training study showed that in 7-10 year old children an additional training task involving imagery vs. lexical processing did not affect the learning of novel words (Ponari et al., 2020). In our adult sample, the specific training task effect might reflect a relative disadvantage for imagery and/or a relative advantage for rephrasing. In the first sense, (vivid) emotional imagery potentially resulted in richer emotional information as expected, but this (non-linguistic) richness might have led to a (relatively) more effortful semantic integration, which has previously been shown to slow down LDT reaction times (Palazova et al., 2013; Rodríguez-Ferreiro et al., 2011). Further, salient emotional information during imagery might have claimed attentional resources at the expense of the less salient linguistic information and its associations (Murphy & Isaacowitz, 2008; Wang et al., 2013). In the second sense, participants might have established more linguistic associations during rephrasing than imagery, which in turn have been shown to facilitate explicit semantic judgments (i.e., concreteness judgments; Pexman et al., 2008) and lexical decisions (Cortese et al., 2018; Recchia & Jones, 2012). Due to their lexico-semantic nature, our performance measures might thus have been prone to show this unexpected relative advantage for the rephrasing compared to the imagery task. Importantly, any task-specific (dis-)advantage was not driven by differences between the duration of or cognitive effort during the training tasks,

as neither the duration (see Appendix D) nor the subjective difficulty (see Appendix E on <https://osf.io/gjc8p/>) differed between groups.

Notably, these post-hoc explanations can also be related to the results of the FPT as well as the LDT and they are not mutually exclusive. Based on the available behavioural measures, it is not possible to disentangle to which degree they contributed to the observed pattern. Further, even though this linguistic training paradigm allows us to directly link observed effects to the controlled linguistic and emotional experience, we cannot infer that the novel concepts were actually grounded in the corresponding linguistic and emotional brain networks. An important next step would thus be to investigate electrophysiological effects at different word processing stages after training to draw more direct conclusions on the neural mechanisms of experiential grounding of abstract concepts (Hauk & Tschentscher, 2013). Finally, we would like to point to the limitations of fundamental research based on laboratory controlled experiential grounding, which can never reach the same level of situatedness and complexity as real-world experience. Complementary to our lab-controlled findings, an analysis of free listing data on concepts formed by real world experience during the first Italian lockdown revealed that social-emotional information plays a crucial role in characterizing representations of COVID-related concepts (Mazzuca et al., 2021). This example illustrates how our findings on experiential grounding of novel abstract concepts could be related to highly topical real-life experiential grounding during the pandemic.

In conclusion, we successfully induced completely novel abstract emotional and neutral concepts based on fully controlled material provided in a purely linguistic training paradigm. This training paradigm is made fully available for the scientific community in the supplementary material (<https://osf.io/gjc8p/>). Our results confirm the importance of linguistic experience and additional deep lexico-semantic processing in the form of rephrasing for abstract concepts in adults. Further, our findings support the notion that emotional content enriches semantic representations, while a (vivid) explicit emotional imagery had relatively

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detrimental effects on the chosen lexical performance measures compared to lexical rephrasing during training. By supporting the direct role of experience in the acquisition, representation and processing of novel abstract concepts the developed training paradigm makes way for future research to dig deeper into how grounded mechanisms apply to abstract conceptual knowledge.

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