Thematic relations outperform taxonomic relations in a cued recall task

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Abstract

Prior knowledge has long been known to influence retention of newly experienced information. In particular, known semantic associations across items facilitate subsequent memory for these items, and this effect has been shown to increase with measures of semantic relatedness. In the field of categories and concepts, the processing of taxonomic (e.g., *cup-fork, dog-bird*) versus thematic (e.g., *cup-drink, dog-leash*) conceptual relations can be differentiated at the behavioral and neural levels. However, the effects of these distinct conceptual relations on memory remain unresolved. The current study used a stimulus set consisting of thematic, taxonomic, and unrelated noun-noun word pairs, to shed light on this issue. Our results indicate that pairs with thematic relations lead to improved cued memory performance, followed by taxonomic relations, and finally unrelated pairs. This study provides evidence that conceptual relations differ in the extent to which they facilitate cued memory performance.

Keywords: cued memory; thematic relations; taxonomic relations; semantic memory; categories and concepts

Introduction

Our prior knowledge of the world plays a critical role in determining how we remember newly experienced information (Bartlett, 1932; Piaget, 1929). Previous research has shown that information that is consistent with our prior knowledge is better remembered (Tse et al., 2007; van Kesteren et al., 2010; Wing et al., 2022), while information that is inconsistent is more likely to be forgotten or subject to error (Smith et al., 2000; van Kesteren et al., 2010). This has been attributed to accelerated rates of system consolidation for information congruent with prior knowledge (Farzanfar et al., 2022; Sommer, 2017; Tse et al., 2007, 2011). The effect of prior knowledge has been shown to span multiple learning sessions (Bein et al., 2019), and can be generalized across modalities to generate sensory predictions (Yan et al., 2023).

With respect to perceptual attributions of newly learned information (e.g., phonetic aspects of words), semantic or conceptual knowledge has been shown to provide the greatest improvement in memory performance (Craik & Lockhart, 1972). This enhancement in memory performance has been demonstrated across memory paradigms including free recall (Craik & Tulving, 1975; Howard & Kahana, 2002; Jackson et al., 1986; Schallert, 1976), associative memory (Antony et al., 2022; Brooks et al., 2001; Ramponi et al., 2007), recognition memory (Jacoby et al., 2005; Schallert, 1976), and temporal order memory (Jackson et al., 1986). These semantic effects are not exclusive to lexical memory but extend to studies in the visual modality (Bower & Karlin, 1974; Rust & Palmer, 2021), and more complex stimuli such as narratives (Bellana et al., 2021; Raccah et al., 2022). For this reason, the influential depth-of-processing (DoP) framework proposed by Craik and Lockhart (1972) has termed semantic analysis in memory as the "deepest" level of processing. Nevertheless, a closer look into the DoP framework reveals a lack of objective criteria for "depth" and a lack of principled investigation of variation at the semantic level (Eysenck, 1978; Koriat & Melkman, 1987). As such, semantic processing may itself vary on a continuum with respect to its influence on memory.

To advance this research program, one could consider evidence from the field of categories and concepts (Carey, 2009; Murphy, 2010). This area of research may provide critical insights for developing experimental materials for understanding how semantic knowledge impacts memory. The current study aims to examine how two types of semantic associations drive memory performance: thematic and taxonomic conceptual relations. Thematic relations are based on spatial-temporal co-occurrences or functional ties between concepts (e.g., *dog* and *leash*), while taxonomic (or categorical) relations denote the similarity between concepts based on their shared features (e.g., *dog* and *monkey*). Previous research has supported the notion that thematic processing and taxonomic processing are likely two separate systems for organizing semantic information (see Mirman et al. (2017) for review). For example, preference for these two types of conceptual relations varies across age groups. Previous studies have shown that young children and elderly individuals show a preference for thematic relations, while young through middle-aged adults show a preference for taxonomic relations (Blaye & Bonthoux, 2001; Fenson et al., 1989; Markman & Hutchin-

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son, 1984; Smiley & Brown, 1979). Functional neuroimaging studies have additionally reported a divergence in the neural substrates that support thematic and taxonomic processing (e.g., Kalénine et al., 2009; Lewis et al., 2015). This claim is also supported by lesion evidence. Namely, damage to the anterior temporal lobe (ATL) has been shown to result in taxonomic naming errors (e.g., incorrectly labeling an *apple* stimulus as a *grape*), while damage to the temporoparietal junction (TPJ) results in thematic naming errors (e.g., incorrectly labeling an *apple* stimulus as a *worm*) (Mirman & Graziano, 2012; Schwartz et al., 2011). Taken together, this literature suggests a divergence at the behavioral and neural levels for thematic and taxonomic processing.

Consequently, taxonomic and thematic conceptual relations are likely to have dissociable effects on how associated information is remembered. A handful of past studies have compared memory for these two types of relations but have generated mixed results (Belacchi & Artuso, 2018; Hess et al., 1993; Khan & Paivio, 1988; Rabinowitz & Mandler, 1983; see Discussions for in-depth review). This discrepancy in the literature could be due to substantive differences in experimental procedures (e.g., verb-noun phrases creating implicit themes: Hess et al., 1993; Rabinowitz & Mandler, 1983). Furthermore, previous studies could be confounded by a range of psycholinguistic features (written frequency, word length, concreteness, etc.), which are known to impact memory performance (e.g., Aka et al., 2021; Lohnas & Kahana, 2013). Therefore, any interpretation is entirely contingent on properly controlling for these features across relation types. To address these concerns, this work investigates the difference between thematic, taxonomic, and unrelated associations on cued memory recall performance of noun-noun word pairs. Furthermore, we controlled for a wide range of psycholinguistic features which are known to influence memory performance.

Methods

Participants

Native English-speaking participants (n=109) were recruited from New York University. Participants were excluded based on several criteria: (1) survey responses that indicated either poor comprehension of the task instructions or failure to provide undivided attention to the task (n=15); (2) study responses where more than 10 trials for any of the conditions were left unanswered (n=14); (3) incomplete survey responses (n=1). In total, 79 participants were included in the analyses presented in this work (59 females; M_{age}=19.21, SD_{age}=1.12, age range: 17-24). The experiment was administered online and lasted approximately one hour. The study was approved by the local institutional review board (New York University's Committee on Activities Involving Human Subjects).

Materials

To create our stimuli, we subsetted a previously published stimulus set (Lewis et al., 2015), which consists of word pairs that are either taxonomically or thematically related. This stimulus set consists of 150 target words, each of which is paired with both a taxonomically related word (taxonomic prime) and a thematically related word (thematic prime), resulting in 300 primes. Each taxonomic pair is related by sharing a common superordinate category (e.g., *dog-mule, coffee-nectar, zoo-aquarium*) and each thematic pair is related by sharing a spatial-temporal or functional tie (e.g., *candles-cake, pompom-cheerleader, apple-peeler*). Each pair of words was carefully designed to avoid possessing both thematic and taxonomic relations (Lewis et al., 2015). The target words consist of six semantic categories (25 words each): animate/natural objects, clothing, food, tools/artifacts, household, and transportation. In the present study, we used 75 targets with their taxonomic primes, and the other 75 with their thematic primes. The selection was determined to minimize difference between the two conditions across several psycholinguistic features (e.g., word length, word frequency, concreteness, etc.)

Additionally, we generated 75 unrelated pairs (150 words) that do not have any salient intra-pair taxonomic or thematic relations. These pairs are intended to serve as a baseline condition. The procedure for generating unrelated pairs is as follows: 1) We selected 6875 nouns from the English Lexicon Project (ELP, Balota et al., 2007) that were within the ranges of a variety of linguistic features from the Lewis et

Table 1: Example groupings of items into thematic, taxonomic, and unrelated pairs.

thematic		**taxonomic**		**unrelated**	
skirt	lady	actress	psychic	valve	rum
marathon	runner	boxer	gymnast	drawers	bloodhound
cake	candles	hook	rod	missile	magnet
soup	spoon	owl	sparrow	softball	calf
vulture	carcass	lock	latch	golf	tray
spaghetti	fork	airplane	taxi	cod	hill
ribbon	braid	script	magazine	cannon	kidney
grave	tombstone	stamp	smudge	jacket	pregnancy
razor	beard	lamp	flashlight	motel	chess

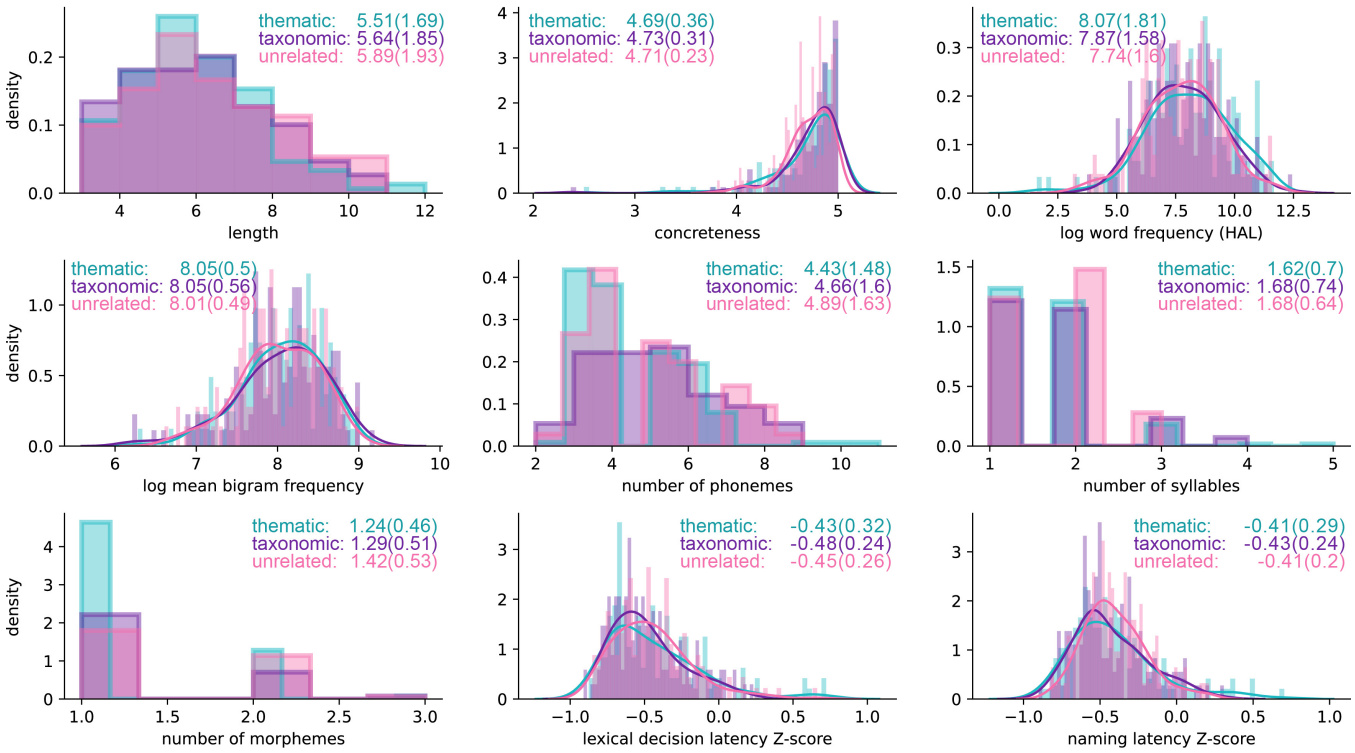

Figure 1: **Distributions of psycholinguistic features for thematic, taxonomic, and unrelated word stimuli.** *We selected words in each of the thematic, taxonomic, and unrelated conditions, such that their distributions overlap in terms of word length, concreteness, log of written word frequency, log of bigram frequency, number of phonemes, number of syllables, number of morphemes, and Z-scores for two behavioral tests, including lexical decision latency and naming latency. The features for these words were acquired from the English Lexicon Project (Balota et al., 2007).*

al. (2015) stimulus set. 2) To further control for the distributions of several critical features, we simulated the distributions of psycholinguistic features in Lewis et al.'s (2015) stimuli by separating the distribution of each feature into five bins, calculating the proportion of words contained in each bin, and sampling words from the ELP to match these proportions. This reduced the possible items to 206 words, matching the distributions across the three conditions. This control is critical as many of these psycholinguistic features are known to reliably influence memory performance (e.g., Aka et al., 2021; Lohnas & Kahana, 2013). Finally, we computed all pairwise semantic similarities (cosine similarity) using a pre-trained autoencoder model (Google Word2Vec; Mikolov, Chen, et al., 2013; Mikolov, Sutskever, et al., 2013); To create the unrelated condition, we picked 75 word pairs with the lowest similarity values while excluding duplicate words. Example groupings of word pairs are shown in **Table 1** (see *link to OSF Project* for full stimulus set). The distributions of psycholinguistic features across pairs belonging to each condition can also be found in **Figure 1**. Notably, semantic similarity computed across thematic (M=0.34, SD=0.12) and taxonomic (M=0.38, SD=0.13) pairs are largely equivalent, while unrelated word pairs show low overall similarity (M=0.0005, SD=0.0008).

Task design

The experiment consisted of 10 blocks. In each block, participants were exposed to 21 word pairs, with each pair shown on the screen for 3 seconds. The presentation of each pair was separated by a 1-second inter-trial interval, with a white fixation shown on the screen (**Figure 2A**). Immediately after this encoding session, participants completed a cued recall task which included all the previously seen pairs (**Figure 2B**). During each recall trial, one word of a previously shown pair was displayed on the screen as the cue. Participants were instructed to type the word paired with the cue in a text box before pressing "Enter" to submit their response. The word which serves as the cue was randomized across participants. A countdown timer was shown on the bottom of the screen, indicating the remaining time to type the answer out of a 20-second time limit. Participants were encouraged to provide an answer even if they did not know the exact spelling. Reaction times 1) from trial onset to the beginning of typing and 2) from trial onset to the response submission were recorded for each trial. After participants completed each cued recall session, they were immediately provided with their over-

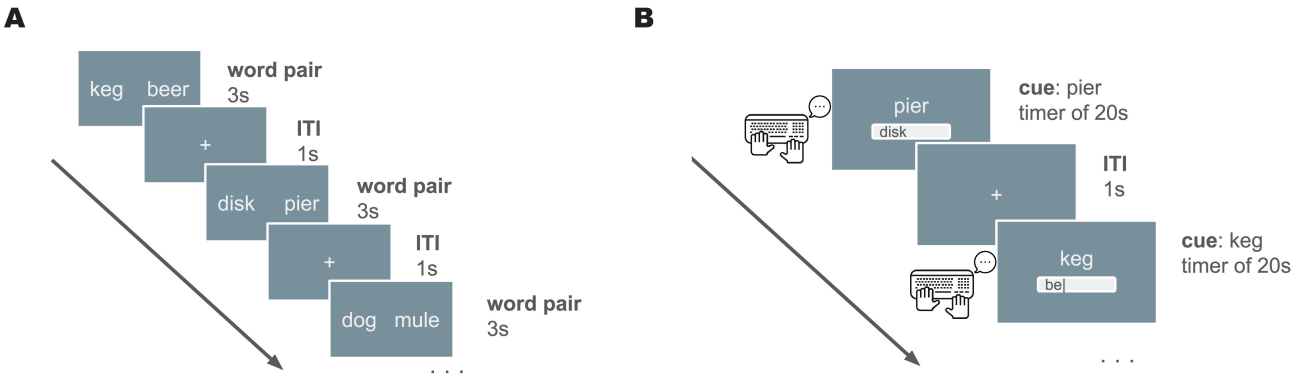

Figure 2: **Experimental paradigm.** *(**A**) During the encoding session, thematic, taxonomic, and unrelated pairs were presented in random order for 3 seconds per pair, with a 1-second ITI. (**B**) At the end of each encoding session, participants performed a cued recall task consisting of the previously presented word pairs. Each test trial was limited to 20 seconds, with a 1-second ITI.*

all percentage correct. After participants completed the entire experiment, they were automatically redirected to an online survey to evaluate their understanding of the study and mnemonic strategies.

Scoring for behavioral data

The accuracy scores and reaction times were averaged for each participant and for each type of relation across blocks. Misspelled words were auto-corrected using TextBlob (Loria, 2018) and plurality-singularity mismatching was corrected using WordNet (Miller, 1995; Fellbaum, 1998). After correction, each participant scored 1 point on a trial if they submitted the correct word and 0 points otherwise. In addition, we analyzed reaction times from trial onset to typing onset and from trial onset to submission. Importantly, both of these measures aim to capture retrieval time.

Statistical analysis

Statistical testing was applied using nonparametric permutation tests. We used paired permutation tests when computing group-level results given our within-subject design. Across these comparisons, we implemented 10,000 permutations to ensure a reliable estimation of the null distribution. Significance was evaluated at $p < 0.05$. Note that a two-tailed statistic is used throughout this work.

Results

In the present study, we tested memory for thematic, taxonomic, and unrelated noun-noun word pairs on cued memory performance. We found that accuracy was the highest for thematic pairs, followed by taxonomic pairs ($t(79) = 9.15$, $p < 0.001$, Cohen's $d = 0.28$), and both had a higher accuracy than unrelated pairs (thematic vs. unrelated: $t(79) = 20.10$, $p < 0.001$, Cohen's $d = 0.67$; taxonomic vs. unrelated: $t(79) = 13.25$, $p < 0.001$, Cohen's $d = 0.38$) (**Figure 3**). This pattern of results was also reflected in participants' reaction times. On average, participants started typing their answers sooner when the word to retrieve was thematically related to the cue than when it was taxonomically related to the cue ($t(79) = 8.84$, $p < 0.001$, Cohen's $d = 0.26$) or when it was unrelated to the cue ($t(79) = 18.09$, $p < 0.001$, Cohen's $d = 0.58$). Participants also began typing faster when retrieving a taxonomically related associate than an unrelated associate ($t(79) = 10.91$, $p < 0.001$, Cohen's $d = 0.33$). Also, this pattern was consistent in the reaction times calculated at the submission

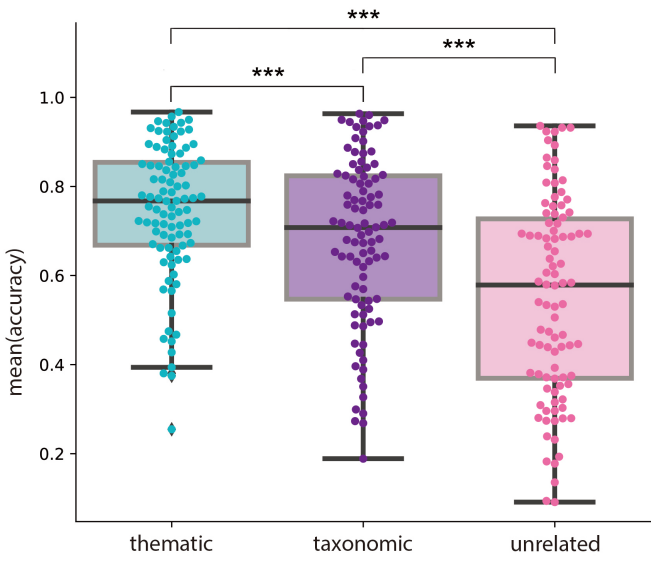

Figure 3: **Accuracy across condition types.** *The average memory accuracy for thematically-related word pairs was significantly higher than taxonomically-related pairs in the cued-recall task, and taxonomically-related pairs were higher than unrelated pairs. *** denotes $p < 0.001$.*

of typed answers. When the word to retrieve and the cue were thematically related, the answer was submitted faster than when they were taxonomically related ($t(79) = 9.31$, $p < 0.001$, Cohen's $d = 0.28$) or unrelated ($t(79) = 18.50$, $p < 0.001$, Cohen's $d = 0.58$), and was submitted faster when they were taxonomically related than when they were unrelated ($t(79) = 10.31$, $p < 0.001$, Cohen's $d = 0.31$)(**Figure 4**).

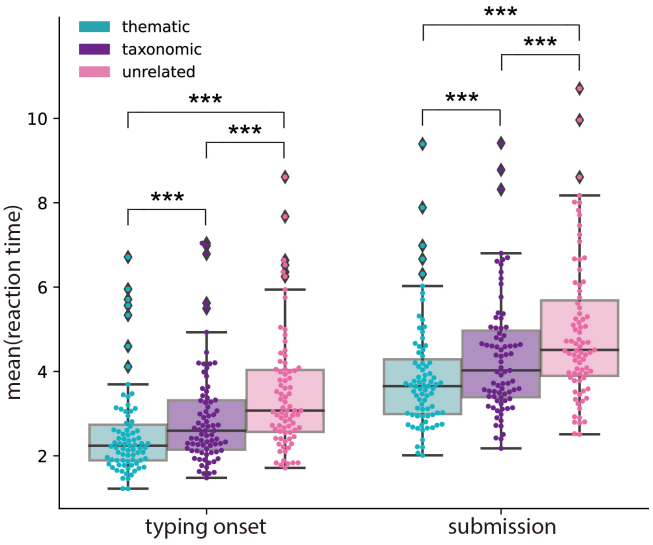

Figure 4: **Reaction time across condition types.** *The average reaction time (in seconds) measured when the participants started typing their answers (RT to typing onset) was significantly shorter for thematic pairs than for taxonomic pairs. Furthermore, both thematic pairs and taxonomic pairs displayed significantly shorter RT to typing onset than unrelated pairs. The average reaction time measured when the participants submitted their typed answers (RT to submission) showed the same pattern of results. *** denotes p <0.001.*

Discussions

The influence of prior semantic knowledge on the acquisition of newly presented information has been extensively studied and supported within the field of cognitive psychology (Brod et al., 2013; Craik & Lockhart, 1972; Fernández & Morris, 2018). Nevertheless, how well-characterized types of semantic associations influence memory retention remains unresolved. This study examines the differential effects of thematic and taxonomic conceptual relations on cued memory performance. We used a stringently controlled stimulus set of thematic and taxonomic word stimuli (Lewis et al., 2015), as well as unrelated pairs as a baseline condition. The results of the current study indicate a strong advantage of thematic conceptual relations over taxonomic conceptual relations and an advantage of both relations over unrelated word pairs.

This finding calls into question the reason(s) why thematic conceptual relations demonstrate a memory benefit with respect to taxonomic relations. Under one account, thematic relations may serve to activate a spatiotemporal context (Bellana et al., 2021), which underpins our conception of episodic memory (Tulving, 1972). Thematic associations may additionally include functional or causal ties, which have been suggested to drive memory performance (Chen et al., 2014; Lee & Chen, 2022; Sanders & Noordman, 2000). Relatedly, it is possible that thematic relations constrain memory search during retrieval with respect to taxonomic relations. That is, themes may have fewer possible constituents (e.g., there are more items that are a part of the category *animal* than items associated with a particular theme). Nevertheless, this particular advantage may be susceptible to category size and theme complexity (Landauer & Freedman, 1968; Landauer & Meyer, 1972). When the taxonomic category is extremely narrow or when the scene or event involves more information, the taxonomic relations may offer a more constrained hypothesis space than the thematic relations. To our knowledge, however, this hypothesis has not been tested in prior work. Another possibility lies in the complex nature of thematic relations. In particular, previous neuroimaging studies have suggested that thematic processing may encompass some degree of taxonomic processing (Lewis et al., 2015; Xu et al., 2018; Zhang et al., 2021). Therefore, thematic relations may additionally benefit from the advantage associated with taxonomic processing. Future research which aims to quantify thematic and taxonomic relations on a continuous scale (e.g., through analyzing subjective ratings) would be useful for understanding this overlap as well as the parametric effect of these conceptual relationships.

Importantly, several prior studies have generated mixed results regarding the influence of different conceptual relations on memory performance. This divergence might be due to procedural differences of the experiments. For instance, some studies grouped stimuli by different conceptual relations and provided overarching theme or category labels during encoding (Hess et al., 1993; Rabinowitz & Mandler, 1983). This has been suggested to bias participants' interpretation of the stimuli (Khan & Paivio, 1988). The materials themselves might also be biasing irrespective of the paradigm, as these studies used verb-noun phrases (Hess et al., 1993; Khan & Paivio, 1988; Rabinowitz & Mandler, 1983), which could already be activating an event or scene concept, entailing thematic processing. Using noun-noun word pairs is a more advantageous approach because the part of speech does not initiate a learning context for any type of conceptual relation. To our knowledge, other studies using only noun words have not used paradigms that could validly investigate the effects of conceptual relations. For example, a more recent study applied lists of nouns, with one number word inserted into each list, that are thematically (e.g., *light*-eight-*heat*-*fire*), taxonomically (e.g., *shop*-*drugstore*-five-*café*), or arbitrarily related (e.g., *party*-*eye*-five-*city*), and the last word of each list was required to be recalled (Belacchi & Artuso, 2018). How-

ever, recalling the last word in each list does not always guarantee that participants would form associations between the words within each list, as such tasks could be performed by only paying attention to every last word. In order to rule out this potential confound, our experiment did not specify which word was to be recalled and either word could be cued during recall. In addition, past research argued for an age difference in benefiting from different conceptual relations during retrieval, in particular an advantage for taxonomic relations among young to middle-aged adults (e.g., Belacchi & Artuso, 2018). Nevertheless, our result showed that thematic relations still outperform taxonomic relations in adults aged from 18 to 24 years. As such, this work shows that a thematic advantage can be found in young adults and highlights a potential developmental distinction in memory for such relations which can be explored in future research. The study can also be extended to different age groups to test the age preference of conceptual relations that previous literature have suggested.

There are limitations of the current approach that should be acknowledged. First, we did not control for the hierarchical nature of taxonomic conceptual relations (i.e., whether certain relations are subordinate or superordinate with respect to one another). Second, as discussed above, we did not control for category size (i.e., the number of members belonging to each category), which may have consequences for memory search during recall. Finally, it is possible that thematic relationships are simply easier to infer using the cued recall design, without explicit memory of the cued item. This possibility could be better understood through analyses which evaluate incorrect answers and whether these are largely thematic or taxonomic with respect to the cue. We hope that this work can inform future research aimed at understanding the influence of semantic knowledge on memory and open up questions regarding theoretical concerns of current models of prior knowledge.

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References

Aka, A., Phan, T. D., & Kahana, M. J. (2021). Predicting recall of words and lists. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, *47*(5), 765–784. doi: 10.1037/xlm0000964

Antony, J. W., Romero, A., Vierra, A. H., Luenser, R. S., Hawkins, R. D., & Bennion, K. A. (2022). Semantic relatedness retroactively boosts memory and promotes memory interdependence across episodes. *eLife*, *11*(e72519). doi: 10.7554/elife.72519

Balota, D. A., Yap, M. J., Hutchison, K. A., Cortese, M. J., Kessler, B., Loftis, B., Neely, J. H., Nelson, D. L., Simpson, G. B., & Treiman, R. (2007). The english lexicon project. *Behavior Research Methods*, *39*(3), 445–459. doi: 10.3758/bf03193014

Bartlett, F. C. (1932). *Remembering: A study in experimental and social psychology*. Cambridge University Press.

Bein, O., Trzewik, M., & Maril, A. (2019). The role of prior knowledge in incremental associative learning: An empirical and computational approach. *Journal of Memory and Language*, *107*, 1-24. doi: https://doi.org/10.1016/j.jml.2019.03.006

Belacchi, C., & Artuso, C. (2018). How taxonomic and thematic associations in semantic memory modulate recall in young through old-old adults. *Psychology and Aging*, *33*(7), 1060–1069. doi: 10.1037/pag0000297

Bellana, B., Mahabal, A., & Honey, C. J. (2021). Narrative thinking lingers in spontaneous thought. doi: 10.31234/osf.io/gxzyj

Blaye, A., & Bonthoux, F. (2001). Thematic and taxonomic relations in preschoolers: The development of flexibility in categorization choices. *British Journal of Developmental Psychology*, *19*(3), 395–412. doi: 10.1348/026151001166173

Bower, G. H., & Karlin, M. B. (1974). Depth of processing pictures of faces and recognition memory. *Journal of Experimental Psychology*, *103*(4), 751–757. doi: 10.1037/h0037190

Brod, G., Werkle-Bergner, M., & Shing, Y. L. (2013). The influence of prior knowledge on memory: A developmental cognitive neuroscience perspective. *Frontiers in Behavioral Neuroscience*, *7*. doi: 10.3389/fnbeh.2013.00139

Brooks, B. M., Gardiner, J. M., Kaminska, Z., & Beavis, Z. (2001). Implicit versus explicit retrieval of surnames of famous people: Dissociative effects of levels of processing and age. *Journal of Memory and Language*, *44*(1), 118–130. doi: 10.1006/jmla.2001.2717

Carey, S. (2009). *The origin of concepts*. Oxford University Press. doi: 10.1093/acprof:oso/9780195367638.001.0001

Chen, Q., Roberson, D., Liang, X., Lei, Y., & Li, H. (2014). Accessing the asymmetrical representations of causal relations and hierarchical relations in semantic memory. *Journal of Cognitive Psychology*, *26*(5), 559–570. doi: 10.1080/20445911.2014.927877

Craik, F. I. M., & Lockhart, R. S. (1972). Levels of processing: A framework for memory research. *Journal of Verbal Learning and Verbal Behavior*, *11*(6), 671–684. doi: 10.1016/s0022-5371(72)80001-x

Craik, F. I. M., & Tulving, E. (1975). Depth of processing and the retention of words in episodic memory. *Journal of Experimental Psychology: General*, *104*(3), 268–294. doi: 10.1037/0096-3445.104.3.268

Eysenck, M. W. (1978). Levels of processing: A critique. *British Journal of Psychology*, *69*(2), 157–169. doi: 10.1111/j.2044-8295.1978.tb01643.x

Farzanfar, D., Spiers, H. J., Moscovitch, M., & Rosenbaum, R. S. (2022). From cognitive maps to spatial schemas. *Nature Reviews Neuroscience*, *24*(2), 63–79. doi: 10.1038/

s41583-022-00655-9

Fellbaum, C. (Ed.). (1998). *WordNet*. The MIT Press. doi: 10.7551/mitpress/7287.001.0001

Fenson, L., Vella, D., & Kennedy, M. (1989). Children's knowledge of thematic and taxonomic relations at two years of age. *Child Development*, *60*(4), 911-919. doi: 10.2307/1131032

Fernández, G., & Morris, R. G. (2018). Memory, novelty and prior knowledge. *Trends in Neurosciences*, *41*(10), 654–659. doi: 10.1016/j.tins.2018.08.006

Hess, T. M., Flannagan, D. A., & Tate, C. S. (1993). Aging and memory for schematically vs taxonomically organized verbal materials. *Journal of Gerontology*, *48*(1), P37–P44. doi: 10.1093/geronj/48.1.p37

Howard, M. W., & Kahana, M. J. (2002). When does semantic similarity help episodic retrieval? *Journal of Memory and Language*, *46*(1), 85–98. doi: 10.1006/jmla.2001.2798

Jackson, J., Michon, J., Boonstra, H., Jonge, D. D., & Harsenhorst, J. D. V. (1986). The effect of depth of processing on temporal judgment tasks. *Acta Psychologica*, *62*(3), 199–210. doi: 10.1016/0001-6918(86)90087-9

Jacoby, L. L., Shimizu, Y., Daniels, K. A., & Rhodes, M. G. (2005). Modes of cognitive control in recognition and source memory: Depth of retrieval. *Psychonomic Bulletin & Review*, *12*(5), 852–857. doi: 10.3758/bf03196776

Kalénine, S., Peyrin, C., Pichat, C., Segebarth, C., Bonthoux, F., & Baciu, M. (2009). The sensory-motor specificity of taxonomic and thematic conceptual relations: A behavioral and fMRI study. *NeuroImage*, *44*(3), 1152–1162. doi: 10.1016/j.neuroimage.2008.09.043

Khan, M., & Paivio, A. (1988). Memory for schematic and categorical information: A replication and extension of rabinowitz and mandler (1983). *Journal of Experimental Psychology: Learning, Memory, and Cognition*, *14*(3), 558–561. doi: 10.1037/0278-7393.14.3.558

Koriat, A., & Melkman, R. (1987). Depth of processing and memory organization. *Psychological Research*, *49*(2-3), 173–181. doi: 10.1007/bf00308684

Landauer, T. K., & Freedman, J. L. (1968). Information retrieval from long-term memory: Category size and recognition time. *Journal of Verbal Learning and Verbal Behavior*, *7*(2), 291–295. doi: 10.1016/s0022-5371(68)80003-9

Landauer, T. K., & Meyer, D. (1972). Category size and semantic-memory retrieval. *Journal of Verbal Learning and Verbal Behavior*, *11*(5), 539–549. doi: 10.1016/s0022-5371(72)80037-9

Lee, H., & Chen, J. (2022). Predicting memory from the network structure of naturalistic events. *Nature Communications*, *13*(1). doi: 10.1038/s41467-022-31965-2

Lewis, G. A., Poeppel, D., & Murphy, G. L. (2015). The neural bases of taxonomic and thematic conceptual relations: An MEG study. *Neuropsychologia*, *68*, 176–189. doi: 10.1016/j.neuropsychologia.2015.01.011

Lohnas, L. J., & Kahana, M. J. (2013). Parametric effects of word frequency in memory for mixed frequency lists. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, *39*(6), 1943–1946. doi: 10.1037/a0033669

Loria, S. (2018). textblob documentation. *Release 0.15*, *2*.

Markman, E. M., & Hutchinson, J. E. (1984). Children's sensitivity to constraints on word meaning: Taxonomic versus thematic relations. *Cognitive Psychology*, *16*(1), 1–27. doi: 10.1016/0010-0285(84)90002-1

Mikolov, T., Chen, K., Corrado, G., & Dean, J. (2013). *Efficient estimation of word representations in vector space.* arXiv. doi: 10.48550/ARXIV.1301.3781

Mikolov, T., Sutskever, I., Chen, K., Corrado, G., & Dean, J. (2013). *Distributed representations of words and phrases and their compositionality.* arXiv. doi: 10.48550/ARXIV.1310.4546

Miller, G. A. (1995). WordNet. *Communications of the ACM*, *38*(11), 39–41. doi: 10.1145/219717.219748

Mirman, D., & Graziano, K. M. (2012). Damage to temporo-parietal cortex decreases incidental activation of thematic relations during spoken word comprehension. *Neuropsychologia*, *50*(8), 1990–1997. doi: 10.1016/j.neuropsychologia.2012.04.024

Mirman, D., Landrigan, J.-F., & Britt, A. E. (2017). Taxonomic and thematic semantic systems. *Psychological Bulletin*, *143*(5), 499–520. doi: 10.1037/bul0000092

Murphy, G. L. (2010). What are categories and concepts? In *The making of human concepts* (pp. 11–28). Oxford University Press. doi: 10.1093/acprof:oso/9780199549221.003.02

Piaget, J. (1929). *The child's conception of the world* (J. Tomlinson & A. Thomlinson, Trans.). Harcourt Brace.

Rabinowitz, M., & Mandler, J. M. (1983). Organization and information retrieval. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, *9*(3), 430–439. doi: 10.1037/0278-7393.9.3.430

Raccah, O., Chen, P., Willke, T. L., Poeppel, D., & Vo, V. A. (2022). *Memory in humans and deep language models: Linking hypotheses for model augmentation.* arXiv. doi: 10.48550/ARXIV.2210.01869

Ramponi, C., Richardson-Klavehn, A., & Gardiner, J. M. (2007). Component processes of conceptual priming and associative cued recall: The roles of preexisting representation and depth of processing. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, *33*(5), 843–862. doi: 10.1037/0278-7393.33.5.843

Rust, N. C., & Palmer, S. E. (2021). Remembering the past to see the future. *Annual Review of Vision Science*, *7*(1), 349–365. doi: 10.1146/annurev-vision-093019-112249

Sanders, T. J. M., & Noordman, L. G. M. (2000). The role of coherence relations and their linguistic markers in text processing. *Discourse Processes*, *29*(1), 37–60. doi: 10.1207/s15326950dp2901_3

Schallert, D. L. (1976). Improving memory for prose: The relationship between depth of processing and context. *Journal of Verbal Learning and Verbal Behavior*, *15*(6), 621–

632. doi: 10.1016/0022-5371(76)90055-4

Schwartz, M. F., Kimberg, D. Y., Walker, G. M., Brecher, A., Faseyitan, O. K., Dell, G. S., Mirman, D., & Coslett, H. B. (2011). Neuroanatomical dissociation for taxonomic and thematic knowledge in the human brain. *Proceedings of the National Academy of Sciences*, *108*(20), 8520–8524. doi: 10.1073/pnas.1014935108

Smiley, S. S., & Brown, A. L. (1979). Conceptual preference for thematic or taxonomic relations: A nonmonotonic age trend from preschool to old age. *Journal of Experimental Child Psychology*, *28*(2), 249–257. doi: 10.1016/0022-0965(79)90087-0

Smith, S. M., Ward, T. B., Tindell, D. R., Sifonis, C. M., & Wilkenfeld, M. J. (2000). Category structure and created memories. *Memory & Cognition*, *28*(3), 386–395. doi: 10.3758/bf03198554

Sommer, T. (2017). The emergence of knowledge and how it supports the memory for novel related information. *Cerebral Cortex*, *27*(3), 1906-1921. doi: 10.1093/cercor/bhw031

Tse, D., Langston, R. F., Kakeyama, M., Bethus, I., Spooner, P. A., Wood, E. R., Witter, M. P., & Morris, R. G. M. (2007). Schemas and memory consolidation. *Science*, *316*(5821), 76–82.

Tse, D., Takeuchi, T., Kakeyama, M., Kajii, Y., Okuno, H., Tohyama, C., Bito, H., & Morris, R. G. M. (2011). Schema-dependent gene activation and memory encoding in neocortex. *Science*, *333*(6044), 891–895. doi: 10.1126/science.1205274

Tulving, E. (1972). Episodic and semantic memory. Oxford, England: Academic Press.

van Kesteren, M. T. R., Rijpkema, M., Ruiter, D. J., & Fernández, G. (2010). Retrieval of associative information congruent with prior knowledge is related to increased medial prefrontal activity and connectivity. *Journal of Neuroscience*, *30*(47), 15888–15894.

Wing, E. A., Burles, F., Ryan, J. D., & Gilboa, A. (2022). The structure of prior knowledge enhances memory in experts by reducing interference. *Proceedings of the National Academy of Sciences*, *119*(26), e2204172119. doi: 10.1073/pnas.2204172119

Xu, Y., Wang, X., Wang, X., Men, W., Gao, J.-H., & Bi, Y. (2018). Doctor, teacher, and stethoscope: Neural representation of different types of semantic relations. *The Journal of Neuroscience*, *38*(13), 3303–3317. doi: 10.1523/jneurosci.2562-17.2018

Yan, C., de Lange, F. P., & Richter, D. (2023). Conceptual associations generate sensory predictions. *The Journal of Neuroscience*, JN–RM–1874–22. doi: 10.1523/jneurosci.1874-22.2023

Zhang, M., Varga, D., Wang, X., Krieger-Redwood, K., Gouws, A., Smallwood, J., & Jefferies, E. (2021). Knowing what you need to know in advance: The neural processes underpinning flexible semantic retrieval of thematic and taxonomic relations. *NeuroImage*, *224*, 117405. doi: 10.1016/j.neuroimage.2020.117405