Title

So many options, so little control: Abstract representations can reduce selection demands to increase children's self-directed flexibility

Journal

Journal of Experimental Child Psychology, 116(3)

ISSN

0022-0965

Authors

Snyder, Hannah R
Munakata, Yuko

Publication Date

2013-11-01

DOI

10.1016/j.jecp.2013.07.010

Peer reviewed

Published in final edited form as:
J Exp Child Psychol. 2013 November ; 116(3): 659–673. doi:10.1016/j.jecp.2013.07.010.

So many options, so little control: Abstract representations can reduce selection demands to increase children's self-directed flexibility

Hannah R. Snyder[a,1] and **Yuko Munakata**[a]

Hannah R. Snyder: hannah.snyder@ucdenver.edu; Yuko Munakata: munakata@cololorado.edu

[a]University of Colorado Boulder, Department of Psychology and Neuroscience, 345 UCB, Boulder, CO 80309, USA

Abstract

Children often struggle to behave flexibly when they must use self-directed goals (e.g., doing homework without prompting) rather than externally-driven goals (e.g., cleaning up when told). Such struggles may reflect the demands of selecting among many potential options, as required for self-directed control. The current study tested whether: 1) 6-year-old children show difficulty selecting among competing semantic representations, 2) providing category labels designed to reduce selection demands improves performance, and 3) such benefits transfer to self-directed flexibility. Selection was measured using the blocked cyclic naming task for the first time with children. Pictures were named repeatedly, in either homogeneous blocks from the same category (e.g., all animals), which create high selection demands due to spreading semantic activation and engage effortful cognitive control, or mixed blocks with each picture from a different category. Children showed robust difficulty in selecting among options, as indexed by RT differences between homogeneous and mixed blocks. Providing subcategory labels designed to reduce selection demands by distinguishing among same-category items (e.g., "A cow is a farm animal. A cat is a pet.") improved selection. Providing superordinate categories (e.g., "A cow is an animal. A cat is an animal.") also improved selection, but these benefits were less robust, and subcategory labels led to greater benefits than superordinate category labels on a subsequent verbal fluency task. These results support a role for subcategory representations in reducing selection demands to aid self-directed flexibility, while suggesting that some children may use superordinate category labels to activate subcategory representations on their own.

Keywords

cognitive development; endogenous flexibility; selection; blocked cyclic naming; verbal fluency

A fundamental part of growing up is going beyond routines. Children become increasingly skilled over the first years of life at overcoming well-learned habits or their desires in the moment, to instead act on longer-term goals (e.g., to stop playing and start putting away toys

Correspondence concerning this article should be addressed to Hannah R. Snyder, Department of Psychology, University of Denver, Denver, CO 80208, USA. hannah.snyder@ucdenver.edu.
[1]Hannah Snyder currently at University of Denver.

before going outside). Doing so requires actively maintaining goals in working memory, which provide top-down support for goal-relevant thoughts and behaviors, allowing children to break out of habits and switch from one task to another (e.g., Davidson, Amso, Anderson, & Diamond, 2006; Marcovitch, Boseovski, & Knapp, 2007; Munakata, Chatham, & Snyder, 2012; Towse, Lewis, & Knowles, 2007). Children's early successes often occur with exogenous (externally-driven) goals (e.g., putting away toys when told), and only later with endogenous (self-directed) goals (e.g., working through a series of homework tasks without being prompted). For example, four-year-olds can switch to a new rule for sorting cards when an adult tells them when to switch and what the new rule is (e.g., Zelazo, 1996). However, when children are told to sort cards in "a new way," without being told what rule to switch to, children younger than seven perseverate, continuing to use the old rule (e.g., Jacques & Zelazo, 2001; Smidts, Jacobs, & Anderson, 2004).

With tasks that require even more self-direction, performance continues to improve through adolescence (Ardila, Rosselli, Matute, & Guajardo, 2005; Kavé, 2006; Kavé, Kigel, & Kochva, 2008; Matute, Rosselli, Ardila, & Morales, 2004; Riva, Nichelli, & Devoti, 2000; Sauzéon, Lestage, Raboutet, N'Kaoua, & Claverie, 2004). For example, in the verbal fluency task, participants are asked to say as many items as they can in one minute from a category (e.g., animals). In order to generate many words, participants must both cluster (produce words within semantic subcategories) and switch (shift between subcategories; e.g., Troyer, Moscovitch, & Winocur, 1997). People must thus endogenously detect the need to switch (e.g., when they cannot think of more zoo animals) and select what to switch to (e.g., pets, farm animals, or ocean animals), without any external cues as to when to switch and what to switch to. Children often fail, for example, naming five zoo animals and declaring there are no more animals, even though they know many other types of animals (Snyder & Munakata, 2010).

What makes such self-directed flexibility more demanding and later to develop than externally-driven flexibility? One possibility is that self-directed control requires selecting among many options. In externally-driven tasks, participants are told what to do and/or when to do it, so selection demands are minimal. In contrast, when there are multiple options (e.g., multiple animals to choose among), competition among them must be resolved in order to select a response, a process that is time-consuming and relies on prefrontal cognitive control mechanisms (e.g., Hirshorn & Thompson-Schill, 2006; Snyder, Banich, & Munakata, 2011).

This idea that selection demands contribute to the later mastery of self-directed flexibility has been tested in the verbal fluency task with children (Snyder & Munakata, 2010). Before completing a verbal fluency task (e.g., name all the animals you can think of), five-year-old children were provided with either: 1) subcategories (farm animals, zoo animals, and ocean animals), designed to reduce selection demands or 2) exemplars (e.g., goat, rhinoceros, and whale). Subcategory labels were expected to activate associated abstract representations, which provide top-down support for the associated subcategory members. Such support should reduce selection demands by focusing searches within a subcategory (e.g., on the more limited pool of zoo animals as opposed to all animals; Figure 1a), or, when a subcategory is exhausted, by focusing searches among remaining subcategories (e.g., among the small set of remaining animal subcategories) and then within the chosen subcategory. As predicted, providing children with subcategory labels before completing verbal fluency helped them to subsequently endogenously switch among subcategories more than children given exemplars (Snyder & Munakata, 2010). This benefit extended to subcategories that were not provided. Thus, subcategory labels appear to reduce selection demands to aid endogenous control in children.

However, verbal fluency is a complex task involving multiple processes in addition to selection (e.g., Latzman & Markon, 2010; Rende, Ramsberger, & Miyake, 2002; Unsworth, Spillers, & Brewer, 2010), such as detecting the need to switch, retrieving information from semantic memory, and monitoring performance to avoid repeating words. Therefore, the benefit of subcategory labels on verbal fluency performance (Snyder & Munakata, 2010) cannot be definitively attributed to a reduction in selection demands, as labels could have potentially affected other aspects of task performance (e.g., by serving as retrieval cues). Thus, in order to more directly test a potential mechanism by which labels improve cognitive control, in the current experiment we test the role of subcategory labels in a simple task that provides a purer measure of selection: blocked cyclic naming (BCN). In this task, participants repeatedly name pictures as quickly as possible in two conditions: homogeneous blocks of pictures from the same category (e.g., LION, DOG, COW, MOUSE, DEER, SEAL), and mixed blocks with each picture from a different category (e.g., LION, PAJAMAS, BENCH, CAR, SHIRT, TOASTER). The homogeneous condition creates high competition among responses due to spreading semantic activation and engages effortful cognitive control, whereas the mixed condition has low competition (e.g., Schnur, Schwartz, Brecher, & Hodgson, 2006).

Specifically, in speech production tasks including BCN, semantic similarity creates interference, which according to most accounts is due to competition among words that are coactivated due to spreading activation through semantic networks (e.g., Chen & Mirman, 2012; Levelt, Roelofs, & Meyer, 1999; Damian, Vigliocco, & Levelt, 2001). When items are named in a context of high semantic similarity, such as in the homogeneous blocks of the BCN task, there is stronger semantic coactivation among items in the response set (e.g., seeing a picture of a lion not only activates the word *lion*, but partially activates representations of the other animals in the block, because they are associated with one another in semantic memory; e.g., Maess, Friederici, Damian, Meyer, & Levelt, 2002). These coactivated representations then compete for production, such that production of the target word (e.g., *lion*) is delayed until this competition is resolved (e.g., Damian et al., 2001; Maess et al., 2002).

While this task seems very simple, there is strong evidence that naming pictures in the homogeneous condition does create interference as posited by these speech production theories, and thus requires effort and prefrontal cognitive control mechanisms, specifically selection among competing options. Healthy adults are slower to name pictures in the homogeneous than the mixed blocks (e.g., Belke, Meyer, & Damian, 2005; Damian, 2003; Damian et al., 2001; Kroll & Stewart, 1994; Maess et al., 2002). Furthermore, naming pictures in the homogeneous compared to the mixed blocks activates the left ventrolateral prefrontal cortex (Schnur et al., 2009), which has been shown to support selection across multiple language production tasks (e.g., Brass & Cramon, 2004; Kan & Thompson-Schill, 2004; Snyder et al., 2011; Thompson-Schill, D'Esposito, Aguirre, & Farah, 1997). Likewise, patients with damage to this area of prefrontal cortex make semantic errors and are much slower to respond during the homogeneous condition of the BCN task (Schnur et al., 2006; 2009; Schnur, Lee, Coslett, Schwartz, & Thompson-Schill, 2005; Scott & Wilshire, 2010).

However, children have never been tested on this task, nor have any studies experimentally manipulated selection demands in the BCN task. In the current study, we tested whether six-year-old children show difficulty selecting among options, as indexed by slower RTs to name pictures in homogeneous relative to mixed blocks. We selected this age group to build closely on prior work suggestive of a role for selection demands in the development of self-directed flexibility (five-year-olds were tested in Snyder & Munakata, 2010), and based on considerations from our BCN piloting with five- and six-year olds (six-year-olds readily completed more blocks of trials, which we opted to maximize given that this was the first test of this paradigm with children).

At this age, children have difficulty selecting among response options in other contexts, where the conflict is directly presented in the task stimuli–for example, conflicting shape, size and color cues for sorting cards (Blackwell, Cepeda, & Munakata, 2009), flanker arrows that point in the opposite direction as the central arrow (e.g., Rueda, Posner, & Rothbart, 2005), or sentences where the emotional prosody and semantic meaning are in conflict (e.g., Morton, Trehub, & Zelazo, 2003). However, there has been little research on children's ability to select among competing semantic representations that are entirely internal, probably because most tasks used to study these processes in adults are not suitable for young children. This is an important gap in the literature because many selection demands in the real world occur between internal semantic representations, rather than external sensory stimuli. For example, we must constantly select among multiple words when speaking (e.g., Snyder et al., 2010) and multiple activities when planning our day (e.g., Burgess et al., 2006). We therefore adapted the BCN task for children to provide a window into these internal selection processes during development.

We also introduced three labeling conditions to manipulate selection demands. Before each block, children were shown the pictures that would appear in the next block and were asked to name them one at a time. In the control condition, the experimenter simply repeated the name of the item (e.g., "Yes, that's a lion, it's a picture of a lion."). In the subcategory condition, the experimenter provided a subcategory label designed to *reduce* selection demands by making each item more distinct from competitors (e.g., "Yes, that's lion, and a lion is a zoo animal," "Yes, that's a dog, and a dog is a pet."). Specifically, we posit that providing subcategory labels will activate subcategory representations that provide top-down support for the relevant subcategory item, helping it to more easily win out over competing items from other subcategories (e.g., thinking of the subcategory label *pet* helps to activate the word *dog*, rather than the names of other animals in the block, which belong to other subcategories, reducing interference from these other animal names when naming the picture of the dog; Figure 1b). If subcategory information reduces selection demands as predicted, children in the subcategory condition should have significantly lower BCN interference than children in the control condition.

In the superordinate label condition, the experimenter provided a superordinate category label (e.g., "Yes, that's a lion, and a lion is an animal," "Yes, that's a dog, and a dog is an animal."). These superordinate category labels may or may not carry the same benefits for selection as subcategory labels. One possibility is that hearing these superordinate labels might *increase* selection demands by making each item more similar to competitors (e.g., by drawing attention to the fact that lions and dogs are both animals), leading to the prediction that children in the superordinate condition should have significantly *higher* interference than those in the control condition (Figure 1c). Alternatively, providing superordinate category labels could lead children to then think of distinguishing subcategory information, activating lower level categories that reduce selection demands (e.g., hearing that lions and dogs are both animals could prompt children to think about what specific types of animals they are, Figure 1d), leading to the prediction that children in the superordinate condition should have significantly *lower* interference than those in the control condition.

Following the BCN task, children completed the verbal fluency task, with one category that was the same as a category they had experienced in the BCN task, and with one category that was novel. The verbal fluency task allowed us to test whether facilitation or interference from the BCN labeling manipulation transfers to self-directed switching. Such transfer is important for informing understanding of what drives labeling effects in the BCN task.

Specifically, since BCN and verbal fluency are posited to have selection demands in common, but are quite different from one another in other ways, transfer would suggest that the BCN labeling manipulation has a general effect on selection, rather than only a task-specific effect on some other aspect of the BCN task. Such transfer might be expected, as previous research has demonstrated that interference from naming homogeneous sets of pictures can generalize to new pictures in the same category (Belke et al., 2005). Thus, in the control condition, and perhaps to an even greater extent in the superordinate condition if it increases interference as in Figure 1c, repeatedly naming pictures in a category should build up interference that impairs subsequent switching for that category during verbal fluency as compared to a novel category. In contrast, if subcategory labels reduce the build up of interference as predicted, children in the subcategory condition should not have reduced switching during verbal fluency for the category they named during BCN compared to a novel category. Thus, we predict that the BCN labeling condition should interact with the verbal fluency category, such that children in the superordinate and control conditions perform relatively better in the novel verbal fluency category compared to the verbal fluency category they named during BCN, while children in the subcategory condition do not have a disadvantage on the category named during BCN.

Method

Participants

Participants were 123 six-year-old children (mean age 76.54 months, SD = 3.07, range 71.3–81.2 months, 55% girls). Given the linguistic nature of the tasks, all participants were monolingual English speakers. Participants were randomly assigned to the control or subcategory condition (41 participants in each condition), or were assigned to the superordinate condition (41 participants), which was run at a later time. An additional 12 participants were excluded due to fussiness (6 control, 6 subcategory), three participants due to bilingualism (one in each condition) and one due to parental interference (control). To be included in the data analyses, participants needed to have usable data for half of the blocks in the BCN task (see Blocked Cyclic Naming Task); an additional 19 children participated but had too few blocks of data for inclusion (7 control, 7 subcategory, 5 superordinate category). In addition, two children did not complete the verbal fluency task and Expressive Vocabulary Test (EVT) due to fussiness. The somewhat high attrition rate can be attributed to two factors. First, the BCN task is long and can be boring for children this age, and we let them stop early if they wished. Also, fewer children knew the names of several of the picture stimuli than our initial piloting suggested, leading to additional children dropped because they did not have enough blocks where they correctly named all items in the labeling phase (see Labeling Phase). Parents provided informed consent, and the study was approved by the university IRB.

Procedure

Children were tested individually in a quiet room during a single session lasting approximately one hour. Children were seated at a table with the experimenter, and parents sat quietly in the back of the room. Between tasks, children were given a short break and picked out a sticker or small prize. All children completed the BCN task first, followed by the verbal fluency task, and finally the Expressive Vocabulary Test (EVT). The entire session was recorded with a digital audio recorder for later coding, as described in Coding and Analysis.

Blocked Cyclic Naming Task—The BCN tasks was identical for children in the three conditions, except for the key manipulation in the labeling phase, when children in the control condition heard exemplar labels, children in the subcategory condition heard subcategory labels, and children in the superordinate condition heard superordinate category labels.

Stimuli and design: Stimuli were 36 colored pictures, with six pictures each from six categories (toys, vehicles, furniture, clothing, appliances, and either animals or foods). Because we wished to examine how each BCN condition affected verbal fluency task performance on a novel category and on a category included in the BCN task, half of the participants completed a version of BCN with animals included, and half with foods included. Each picture within a category belonged to a separate subcategory (e.g., fruit, vegetable, dessert, snack food, breakfast food, and lunch food for the food category).

Pictures were presented in 12 blocks of six pictures each: six homogeneous (H) blocks (all pictures from the same category) and six mixed (M) block (one picture each from each of the six categories). Block order was counterbalanced within the task but kept constant across participants (M, H, H, M, M, H, H, M, M, H, H, M) to minimize extraneous sources of variance for individual differences analyses. Within each block, there were four cycles, in which each picture was presented once in semi-random order, with the constraint that the picture at the end of one cycle was not the same as that at the beginning of the next cycle, so that no picture appeared twice in a row.

Labeling phase: The key manipulation between conditions occurred in the labeling phase. Immediately before beginning each block, children were shown each picture in the block in a printed booklet. Children were asked to name the pictures one at a time. In the control condition, when children named the picture correctly the experiment said: “Yes, that’s a [picture name], it’s a picture of a [picture name].” In the subcategory condition, the experimenter said “Yes, that’s a [picture name], a [picture name] is a [subcategory name]” (e.g., “Yes, that’s an apple, an apple is a fruit.”). In the superordinate condition, the experiment said: “Yes, that’s a [picture name], a [picture name] is a [superordinate category name]” (e.g., “Yes, that’s an apple, an apple is a food.”). Names were counted as correct if they were in the same subcategory as the intended name (e.g., if a child named the picture of the lion “tiger” this was acceptable, since both are zoo animals), and the experimenter used the same word as the child in these cases. If the child did not name a picture correctly, the script was the same except that the experimenter said “Good guess, but that’s a [picture name],” instead of “Yes, that’s a [picture name].” Blocks for which a child did not know all the picture names were dropped from analysis, and children needed at least three each analyzable homogeneous and mixed blocks to be included.

Testing phase: After the labeling phase for each block, the experimenter said “Nice job! Now I’m going to show you those pictures on the computer, and I want you to tell me what they are as fast as you can. I bet you can go really fast, can’t you? Are you ready? OK, here we go!” The pictures were then presented on the computer one at a time in the center of the screen, with the six pictures repeated across four cycles, as described in Stimuli and Design. Each picture remained on the screen until the child named the picture, at which point the experimenter pushed a button to advance to the next trial. This produced a chime sound (used for coding as described below), followed by a blank screen for 500 ms and then the next picture. After each block, children were told “Great job! Are you ready to name some more pictures?” followed by the labeling phase for the next block.

Coding: To ensure accurate and unbiased coding of children’s RTs, voice onset times for each trial were coded from digital audio recordings using the software program Penn TotalRecall (http://memory.psych.upenn.edu/TotalRecall). Trained research assistants marked the beginning of each response by navigating in small time steps through the recording until the first phoneme of each word was detected. Error trials were removed. RTs

<200 ms, >10,000 ms, or greater than three standard deviations above the participant's mean RT were trimmed. RTs were natural log transformed to remove skew and z-transformed within subjects to remove baseline differences in RT. Interference was calculated as the z-RT difference between the homogeneous and mixed blocks, for each cycle individually and across all cycles. Interference is the standard and preferred measure for this task, because raw RTs are affected by large individual differences in overall speaking rate, which are not of interest. Since the homogeneous and mixed blocks differ only in the relevant grouping of the pictures, the z-transformed difference in RT between them provides a sensitive index of interference unconfounded by such overall differences in speaking rate.

Verbal Fluency Task—In the verbal fluency task, children were asked to generate words from two semantic categories (animals and foods, with order counterbalanced across participants), after first completing a practice category (things in a house) to familiarize them with the task. One minute was given for each category. To make the task engaging for children it was presented as a game. Children were given a clear plastic cup into which the experimenter placed a small pompom for each word the child produced. A one-minute sand-timer was used to help motivate children to stay on-task. Children were told: "We're going to play a game where we think of lots and lots of words. I bet you're really good at thinking of words, aren't you? I'll tell you what kinds of words to think of, and every time you tell me one, I'll put a pompom in your cup. Let's see how many pompoms you can get before all the sand is gone. I'll bet you can get a lot! And when we are all done thinking of words, you can trade the pompoms for some stickers." Before each category, the experimenter said: "This time I want you to tell me as many [category name] as you can think of. Can you think of lots and lots of [category name]? Ready, go!" If there was a pause of 10 s or more between items, the child was prompted ("Good job, can you tell me some more [category name]?").

Coding: Verbal fluency data were coded as in Snyder and Munakata (2010). Children's responses were transcribed from audio recordings, and coded by the experimenter and two independent raters blind to data on all other tasks. Coders identified clusters of semantically or phonologically related items (e.g. "lion, tiger, cheetah" when producing animals). A weighted switch score was calculated as follows: one point was awarded for each switch after a cluster of two related items, two points for a switch after three related items, three points for switch after four related items, and so forth. A weighted switch score was used because it reflects increasing confidence as cluster size increased that children were truly clustering and switching. Unweighted scoring systems (e.g. Troyer et al., 1997), which count every transition between subcategories (including between single, unclustered items) equally, have been criticized for confounding switching with a failure to cluster (e.g. Abwender, Swan, Bowerman, & Connolly, 2001). Abwender and colleagues (2001) therefore suggest counting only switches after clusters. As in Snyder and Munakata (2010), we expand on this suggestion by weighting switch scores by cluster size. Inter-rater reliabilities were high (>.8 for all rater pairs).

Expressive Vocabulary Test—The Expressive Vocabulary Test (EVT) was included to control for any differences in vocabulary that could affect performance on the other tasks. The EVT (Pearson Assessments, Bloomington, MN) is a standardized, nationally normed, expressive vocabulary test. Children are shown colored pictures, and asked to name them, or provide synonyms (e.g. "Can you tell me another word for father?"). Testing continues until children reach ceiling (five items in a row incorrect), and raw scores are then converted into a percentile score based on age.

Results

Sample Characteristics

Children in the control, subcategory and superordinate category conditions did not differ in terms of gender, $\eta^2 = 0.07$, $p = .9$. The control and subcategory conditions also did not differ from one another in age, $t(80) = 1.12$, $p = .3$, or vocabulary, $t(78) = -0.40$, $p = .7$. However, children in the superordinate condition were slightly older (77.77 months) than children in the control condition (76.29 months), $t(80) = 2.25$, $p = .027$, and subcategory condition (75.55 months), $t(80) = 3.40$, $p = .001$, and had somewhat lower EVT scores (69.93) than children in the control condition (79.49), $t(78) = 2.27$, $p = .026$, and subcategory condition (81.23), $t(76) = 2.67$, $p = .010$. Thus, age and EVT were included as covariates in all ANOVAs.[1] Outlier analyses were conducted (Cook's D >3 SD above the mean, two rounds), resulting in exclusion of no more than seven outliers from any analysis.

BCN Task Check

As predicted, children showed robust interference in the Blocked Cyclic Naming Task (Table 1). There was significant interference averaging across all cycles (homogeneous – mixed zRT > 0) for children in the control condition (natural log RT homogeneous M = 6.86, SD = 0.20, mixed M = 6.79, SD = 0.18), subcategory condition (natural log RT homogeneous M = 6.88, SD = 0.17, mixed M = 6.85, SD = 0.18), and superordinate category condition (natural log RT homogeneous M = 6.89, SD = 0.16, mixed M = 6.85, SD = 0.16). Children in the control condition had significant interference on every cycle, while those in the subcategory condition had significant or marginally significant interference on all cycles except cycle 1, and children in the superordinate condition had significant or marginally significant interference on all cycles (Table 1).

Effect of BCN condition—BCN data were first analyzed with a 4 (cycle) x 3 (condition) mixed factors ANOVA. There was a significant effect of condition, $F(2,108) = 3.90$, $p = .023$, $\eta^2_{partial} = .067$ (Figure 2). This effect did not vary by cycle (cycle x condition interaction), $F(6, 324) = 0.40$, $p = .9$, and there was no main effect of cycle, $F(3, 324) = 0.11$, $p = .9$. Follow up analyses were conducted with 4 (cycle) x 2 (condition) mixed factors ANOVAs, comparing each pair of conditions. Comparing the subcategory and control conditions, there was a significant effect of condition, $F(1,70) = 6.82$, $p = .011$; $\eta^2_{partial} = .089$. On average across cycles, children in the subcategory condition had significantly less interference (homogeneous – mixed zRT, mean = .09, SD= 0.17) than those in the control condition (mean = .20, SD = 0.17), $t(73) = 2.88$, $p = .005$, $d = 0.67$ (Figure 2). This effect did not vary by cycle (cycle x condition interaction), $F(3, 210) = 0.31$, $p = .8$, and there was no main effect of cycle, $F(3, 210) = 0.26$, $p = .9$.

Comparing the superordinate and control conditions, there was a significant effect of condition, $F(1, 71) = 8.29$, $p = .005$; $\eta^2_{partial} = .105$: On average across cycles, children in the superordinate category condition had significantly less interference (homogeneous – mixed zRT, mean = .11, SD = 0.15) than those in the control condition (mean = .22, SD= 0.15), $t(73) = 3.02$, p=.003, $d = 0.70$. There were no significant effect of cycle, $F(3, 213) = 0.48$, $p = .7$, or cycle x condition interaction, $F(3, 213) = 0.50$, $p = .7$. Comparing the superordinate and subcategory conditions, there was no effect of condition, $F(1, 69) = 0.30$, $p = .6$, or cycle, $F(3, 207) = 1.53$, $p = .2$. There was no overall cycle x condition interaction,

[1]There were small but significant correlations between EVT scores and verbal fluency scores, BCN category, $r = .244$, $p = .007$, $n = 120$, novel category, $r = .287$, $p = .001$, $n = 121$, but not between EVT scores and BCN average interference scores, $r = .005$, $p = .9$, $n = 121$. This illustrates another advantage of the BCN task, in that unlike the verbal fluency task, it is not influenced by individual differences in vocabulary. Age did not correlate significantly with verbal fluency scores, BCN category, $r = -.032$, $p = .7$, $n = 120$, novel category, $r = -.010$, $p = .9$, $n = 121$, or BCN average interference, $r = .137$, $p = .130$, $n = 123$.

F(3, 207) = 1.08, *p* = .4, but there was a marginal quadratic cycle x condition contrast, *F*(1, 69) = 3.44, *p* = .068; $\eta^2_{partial}$ = .048: interference increased sharply in Cycle 4 for the superordinate category condition but not for the subcategory condition (Figure 2). These results indicate that providing superordinate categories can reduce interference in the BCN task relative to providing only exemplars, but that these benefits are not as robust as those of subcategories.

Transfer to verbal fluency—Verbal fluency data were analyzed with 2 (VF category) x 2 (condition) mixed factors ANOVAs, comparing each pair of conditions, with EVT vocabulary and age again entered as covariates for all analyses. Comparing the superordinate category and subcategory conditions, the predicted condition x VF category interaction was significant, *F*(1,71) = 4.19, *p* = .044; $\eta^2_{partial}$ = .056. Children in the superordinate condition switched more during the novel VF category (mean switch score = 4.64, SD = 2.02) than the verbal fluency category they had experienced during BCN (mean switch score = 3.85, SD = 2.10), *t*(40) = 2.29, *p* = .027, *d* = 0.39, suggesting that in the superordinate condition, repeatedly naming pictures in a category builds up interference that impairs subsequent switching for that category during verbal fluency as compared to a novel category. In contrast, children in the subcategory condition did not significantly differ in their switch scores between verbal fluency categories (novel VF category mean switch score = 4.44, SD = 2.02; BCN VF category mean switch score = 4.63, SD = 1.85), *t*(33) = 0.43, *p* =.4, *d* = −0.09 (Figure 3), suggesting that in the subcategory condition, less interference built up during BCN, enabling children to switch just as much during the BCN verbal fluency category as the novel category. There were no significant main effects of VF category, *F*(1,71) = .06, *p* = .8, or condition, *F*(1,71) = 0.10, *p* = .8.

Comparing the control and subcategory conditions, the results were visually consistent with the predicted interaction, with children in the control condition showing a greater tendency to switch more during the novel verbal fluency category than the category they had experienced during BCN, while children in the subcategory condition switched equally in the two verbal fluency categories; however, this interaction did not reach significance, *F*(1,68) = 2.08, *p* = .154 (Figure 3). There were no significant main effects of VF category, *F*(1,68) = 0.09, *p* = .8, or condition, *F*(1,68) = 0.02, *p* = .9. Comparing the superordinate category and control conditions, there was no condition x VF category interaction, *F*(1,73) = 0.06, *p* = .9 (Figure 3), or main effects of VF category, *F*(1,73) = 0.06, *p* = .4, or condition, *F*(1,73) = 0.06, *p* = .8. These results indicate that subcategory information was more effective than superordinate category information in reducing interference in the subsequent verbal fluency task.

These results also suggest that the superordinate category condition does increase interference during verbal fluency, so we conducted exploratory follow-up analyses to determine whether those children in the superordinate condition who experienced interference during verbal fluency might also show increased interference during BCN. We thus split the superordinate category condition sample between those children who showed evidence of interference from BCN during verbal fluency (as indexed by lower switch scores for the verbal fluency category they experienced during BCN than the novel category, *n*=21), and those that did not (*n*=20). A 4 (cycle) x 2 (VF interference group) mixed factor ANOVA showed a significant cycle x VF interference group interaction, *F*(3,102) = 3.51, *p* = .018; $\eta^2_{partial}$ = .094[2]: those children who went on to demonstrate interference from BCN on verbal fluency switching had a large increase in interference during the final cycle of BCN, with significantly more interference in cycle 4 than those children who did not go on to demonstrate interference from BCN during verbal fluency, *t*(34) = 2.90, *p* = .007, *d* = 0.97 (Figure 4). The same result is found in a continuous correlation analysis: for the superordinate condition only, greater BCN cycle 4 interference predicted lower verbal fluency switch scores on the BCN category relative to the novel category, $r = -.367$, $p = .018$, $n = 41$, other conditions *p*s > .5. Thus, some children may have managed to use superordinate category information to reduce interference in the BCN (perhaps by then thinking of distinguishing subcategory information), which also aided them in the verbal fluency task, but other children did not, such that superordinate categories were overall less effective than subcategories in reducing interference in BCN and the verbal fluency task.

Discussion

This experiment demonstrates for the first time that children show robust interference effects in the BCN task, an index of the difficulty of selecting among multiple possible options. While BCN is seemingly a very simple picture-naming task, it taps a fundamental cognitive process: naming pictures in the homogeneous condition creates interference among semantically related items, and in adults, resolving this competition depends on cognitive control mechanisms supported by the left ventrolateral prefrontal cortex, as evidenced by neuroimaging and brain lesion studies (e.g., Schnur et al., 2005; 2006; 2009; Scott & Wilshire, 2010). The simplicity of the task is beneficial: it allows for a more precise, purer measure of selection than more complex tasks that may tap multiple cognitive processes (e.g., verbal fluency) while being appropriate for use with multiple ages, including young children, unlike many tasks that have been used to assess selection in adults (e.g., verb generation). The current study showed that, as in adults, naming pictures in the homogeneous condition of the BCN task elicits semantic competition that slows children's responding, demonstrating that the task can successfully be used to assess selection in children.

While the current study shows that lexical selection processes appear to be qualitatively similar in children and adults, one interesting difference did emerge. In previous studies with adults, interference only emerged on the second cycle, consistent with the theory that interference builds as multiple related items are repeatedly named, causing spreading activation among them (e.g., Belke et al., 2005; Schnur et al., 2006). Contrary to these findings in adults, children in the control and superordinate conditions had significant interference even on the first cycle, which might suggest that activation spreads (and interference builds) more rapidly in children. However, this effect may be due to differences in the tasks rather than age. In previous studies, which found no interference on the first cycle, participants practiced naming all the pictures at the beginning of the study, but did not see or name the pictures in each block before the first cycle. In contrast, in the current study, children named the relevant subset of pictures (and heard the experimenter label them) in the labeling phase immediately before completing each block. Thus, the first cycle in the current study may be equivalent to the second cycle in previous studies. To determine whether the unique pattern we observed, of interference among related words on the first cycle of naming, is driven by children's age or by their practice experience, future studies could test adults on a version of the task with a labeling phase before each block, and children on a version without a labeling phase.

This experiment also demonstrates for the first time that interference in the BCN task can be modulated by how the pictures are initially labeled. Importantly, as predicted, providing subcategory labels to reduce selection demands reduces interference. These results extend

[2]There was also a marginal main effect of cycle for the superordinate condition, $F(3, 102) = 2.50$, $p = .065$, with interference increasing across cycles, but no main effect of VF interference group, $F(1, 34) = 1.07$, $p = .3$. The cycle x VF interference group interaction was specific to the superordinate condition: there was no cycle x VF interference interaction for the control condition, $F(3, 102) = 0.38$, $p = .8$, main effect of cycle, $F(3, 102) = 0.33$, $p = .8$, main effect of VF interference group, $F(1, 34) = 0.00$, $p = 1$, or subcategory condition, $F(3, 105) = 0.10$, $p = .9$, main effect of cycle, $F(3, 105) = 0.21$, $p = .9$, main effect of VF interference group, $F(1, 35) = 1.65$, $p = .2$.

the previous finding that subcategory labels improve switching in the verbal fluency task (Snyder & Munakata, 2010), by demonstrating that subcategory labels also improve performance on a task which more specifically taps selection among competing response options. Specifically, while the results of the previous study were suggestive of a benefit for subcategory representations in reducing selection demands, the complex nature of the verbal fluency task precluded definitively concluding that subcategory labels improved performance via effects on selection, as opposed to other processes involved in verbal fluency. Thus, the current study, using a purer measure of selection, is critical in determining that cueing children with subcategory labels improves their subsequent cognitive control by reducing selection demands. These findings are also consistent with a wider body of evidence that abstract, categorical representations support cognitive flexibility during development (Bunge & Zelazo, 2006; Hanania & Smith, 2010; Kharitonova & Munakata, 2011; Rougier, Noelle, Braver, Cohen, & O'Reilly, 2005) and that labels can facilitate children's use of such representations (e.g., Jacques & Zelazo, 2005; Karbach & Kray, 2007; Lupyan, Rakison, & McClelland, 2007; Luria, 1959).

In contrast, we found that providing children with superordinate category labels (e.g., "A dog is an animal.") can reduce interference in the BCN task relative to providing only exemplars, but these benefits are not as robust as those of subcategories, and do not transfer to reducing interference in the subsequent verbal fluency task. Within the superordinate condition, children who experienced interference during verbal fluency showed increased interference during BCN on the final (fourth) naming cycle, perhaps because these children start thinking of the items in terms of their superordinate category (activated by superordinate labels, unlike in the other conditions), increasing interference. This may not occur until the final cycle of the block because picture names are less strongly associated with their superordinate labels than with their subcategory labels (as quantified by latent semantic analysis, e.g., Landauer & Dumais, 1997). Latent Semantic Analysis is a technique for extracting the similarity of words and passages by analyzing large bodies of text, capturing contextual as well as co-occurrence information, and has been shown to successfully capture human semantic knowledge and behavior (e.g., Griffiths, Steyvers, & Tenenbaum, 2007; Landauer & Dumais, 1997; Snyder & Munakata, 2008). Using the youngest child corpus (General Reading through 3rd grade), the average association strength of picture names with their subcategory labels (.20) was stronger than their average association with their superordinate category labels (.13). With less top-down input from superordinate category labels (Fig. 1), it could take more cycles for the effects of superordinate category labels to build up. The overall pattern of results suggests that some children may be able to use superordinate category information to reduce interference in the BCN task, which also aids them in the verbal fluency task, but other children experience more interference when given superordinate labels. Why might superordinate labels have helped some children?

One possibility is that providing superordinate category labels prompted some children to then think of distinguishing subcategory information, perhaps by cuing them to represent the items in a more abstract, categorical way. For example, by hearing that an apple is food and a sandwich is a food, children may be cued to think about what specific kinds of foods they are. Thus, providing higher-level categories and exemplars may activate lower level categories that reduce selection demands. Evidence consistent with this idea comes from a study in which children were asked to sort pictures that "go well together." Children who sorted by superordinate categories (e.g., putting foods in one pile and vehicles in another) were also better at switching among subcategories during verbal fluency (Snyder & Munakata, 2010). This suggests that the ability to form and activate abstract, categorical representations may generalize from the superordinate to the subcategorical level.

Alternately, superordinate labels may have alerted some children to the presence of competition. It is well established that following a high-conflict trial (e.g., an incongruent trial in a Stroop or flanker task), both children and adults perform better on subsequent high-conflict trials (conflict adaptation; e.g., Botvinick, Braver, Barch, Carter, & Cohen, 2001; Carter & van Veen, 2007; Forster, Carter, Cohen, & Cho, 2011; Larson, Clawson, Clayson, & South, 2012). Following the detection of conflict, control processes are engaged to resolve the response competition and to prevent future decrements in performance by increasing control on subsequent trials (e.g., Carter & van Veen, 2007). Thus, it is possible that superordinate labels (e.g., a dog is an animal and a cow is an animal) draw children's attention to the fact that the pictures are related and thus likely to generate conflict, and cause a conflict-adaptation like increase in cognitive control, which aids subsequent performance. This explanation could be tested by using other means to trigger conflict adaptation, such as having children complete a brief high-conflict task not involving abstract category labels immediately before each BCN block.

In sum, the current studies demonstrate that selecting among competing options is difficult for children, and may be one of the key demands that lead to the prolonged developmental time-course of self-directed flexibility relative to externally-driven flexibility, while providing children with some initial support to reduce selection demands can improve their cognitive control. The real world is replete with demands for such self-directed control–as we move through the tasks in our day we must frequently select among many competing options without strong environmental support. Although we are normally able to successfully deploy cognitive control to select between these competing representations, this ability is slow to develop (e.g., Kavé et al., 2008) and is compromised in a wide variety of clinical disorders (e.g., Robert et al., 1998; Snyder, 2012; Troyer et al., 1998) and in patients with prefrontal damage (e.g., Novick, Kan, Trueswell, & Thompson-Schill, 2009; Robinson, Shallice, & Cipolotti, 2006). Better understanding this fundamental aspect of cognitive control, and the role that labels can play in reducing these selection demands throughout the lifespan, may ultimately have implications for better understanding and treating these deficits, and for helping all of us cope with the many options that we face as we navigate our daily lives.

Acknowledgments

This research was supported by a grant from the National Institutes of Health (RO1 HD37163). Manuscript preparation was supported in part by T32 MH15442. We thank Allison Donmyer and Kelly Brennan for data collection and members of Cognitive Development Center for assistance with data coding.

References

Ardila A, Rosselli M, Matute E, Guajardo S. The Influence of the parents' educational level on the development of executive functions. Developmental Neuropsychology. 2005; 28:539–560.10.1207/s15326942dn2801_5 [PubMed: 15992255]

Belke E, Meyer AS, Damian MF. Refractory effects in picture naming as assessed in a semantic blocking paradigm. The Quarterly Journal of Experimental Psychology Section A: Human Experimental Psychology. 2005; 58:667–692.10.1080/02724980443000142

Blackwell KA, Cepeda NJ, Munakata Y. When simple things are meaningful: Working memory strength predicts children's cognitive flexibility. Journal of Experimental Child Psychology. 2009; 103:241–249.10.1016/j.jecp.2009.01.002 [PubMed: 19278688]

Botvinick MM, Braver TS, Barch DM, Carter CS, Cohen JD. Conflict monitoring and cognitive control. Psychological Review. 2001; 108:624–652.10.1037//0033-295X.108.3.624 [PubMed: 11488380]

Brass M, von Cramon DY. Selection for cognitive control: A functional magnetic resonance imaging study on the selection of task-relevant information. The Journal of Neuroscience. 2004; 24:8847–8852.10.1523/JNEUROSCI.2513-04.2004 [PubMed: 15470151]

Bunge SA, Zelazo PD. A brain-based account of the development of rule use in childhood. Current Directions in Psychological Science. 2006; 15:118–121.10.1111/j.0963-7214.2006.00419.x

Burgess PW, Alderman N, Forbes C, Costello A, Coates LMA, Dawson DR, Channon S. The case for the development and use of "ecologically valid" measures of executive function in experimental and clinical neuropsychology. Journal of the International Neuropsychological Society. 2006; 12:194–209.10.1017/S1355617706060310 [PubMed: 16573854]

Carter CS, van Veen V. Anterior cingulate cortex and conflict detection: An update of theory and data. Cognitive Affective & Behavioral Neuroscience. 2007; 7:367–379.10.3758/CABN.7.4.367

Chen Q, Mirman D. Competition and cooperation among similar representations: Towards a unified account of facilitative and inhibitory effects of lexical neighbors. Psychological Review. 2012; 119:417–430.10.1037/a0027175 [PubMed: 22352357]

Damian MF. Articulatory duration in single-word speech production. Journal of Experimental Psychology: Learning, Memory, and Cognition. 2003; 29:416–431.10.1037/0278-7393.29.3.416

Damian MF, Vigliocco G, Levelt WJM. Effects of semantic context in the naming of pictures and words. Cognition. 2001; 81(3):B77–B86.10.1016/S0010-0277(01)00135-4 [PubMed: 11483172]

Davidson MC, Amso D, Anderson LC, Diamond A. Development of cognitive control and executive functions from 4 to 13 years: Evidence from manipulations of memory, inhibition, and task switching. Neuropsychologia. 2006; 44:2037–2078.10.1016/j.neuropsychologia.2006.02.006 [PubMed: 16580701]

Forster SE, Carter CS, Cohen JD, Cho RY. Parametric manipulation of the conflict signal and control-state adaptation. Journal of Cognitive Neuroscience. 2011; 23:923–935.10.1162/jocn.2010.21458 [PubMed: 20146615]

Griffiths TL, Steyvers M, Tenenbaum JB. Topics in semantic representation. Psychological Review. 2007; 114:211–244.10.1037/0033-295X.114.2.211 [PubMed: 17500626]

Hanania R, Smith LB. Selective attention and attention switching: Towards a unified developmental approach. Developmental Science. 2010; 13:622–635.10.1111/j.1467-7687.2009.00921.x [PubMed: 20590726]

Hirshorn EA, Thompson-Schill SL. Role of the left inferior frontal gyrus in covert word retrieval: Neural correlates of switching during verbal fluency. Neuropsychologia. 2006; 44:2547–2557.10.1016/j.neuropsychologia.2006.03.035 [PubMed: 16725162]

Jacques S, Zelazo PD. The Flexible Item Selection Task (FIST): A measure of executive function in preschoolers. Developmental Neuropsychology. 2001; 20:573–591.10.1207/S15326942DN2003_2 [PubMed: 12002094]

Jacques, S.; Zelazo, PD. On the possible roots of cognitive flexibility. In: Homer, BD.; Tamis-LeMonda, CS., editors. The Development of Social Cognition and Communication. Mahwah, NJ: Lawrence Erlbaum Associates Publishers; 2005. p. 53-81.

Kan IP, Thompson-Schill SL. Effect of name agreement on prefrontal activity during overt and covert picture naming. Cognitive Affective & Behavioral Neuroscience. 2004; 4:43–57.10.3758/CABN.4.1.43

Karbach J, Kray J. Developmental changes in switching between mental task sets: The influence of verbal labeling in childhood. Journal of Cognition and Development. 2007; 8:205–236.10.1080/15248370701202430

Kavé G. The development of naming and word fluency: evidence from Hebrew-speaking children between ages 8 and 17. Developmental Neuropsychology. 2006; 29:493–508.10.1207/s15326942dn2903_7 [PubMed: 16671864]

Kavé G, Kigel S, Kochva R. Switching and clustering in verbal fluency tasks throughout childhood. Journal of Clinical and Experimental Neuropsychology. 2008; 30:349–359.10.1080/13803390701416197 [PubMed: 17852609]

Kharitonova M, Munakata Y. The Role of representations in executive function: Investigating a developmental link between flexibility and abstraction. Frontiers in Psychology. 2011; 2(347):1–12.10.3389/fpsyg.2011.00347 [PubMed: 21713130]

Kroll J, Stewart E. Category interference in translation and picture naming: Evidence for asymmetric connections between bilingual memory representations. Journal of Memory and Language. 1994; 33:149–174.10.1006/jmla.1994.1008

Landauer T, Dumais S. A solution to Plato's problem: The latent semantic analysis theory of acquisition, induction, and representation of knowledge. Psychological Review. 1997; 104:211–240.10.1037//0033-295X.104.2.211

Larson MJ, Clawson A, Clayson PE, South M. Cognitive control and conflict adaptation similarities in children and adults. Developmental Neuropsychology. 2012; 37:343–357.10.1080/87565641.2011.650337 [PubMed: 22612546]

Levelt WJM, Roelofs A, Meyer AS. A theory of lexical access in speech production. Behavioral and Brain Sciences. 1999; 22:1–38.10.1017/S0140525X99001776 [PubMed: 11301520]

Lupyan G, Rakison DH, McClelland JL. Language is not just for talking: Redundant labels facilitate learning of novel categories. Psychological Science. 2007; 18:1077–1083.10.1111/j.1467-9280.2007.02028.x [PubMed: 18031415]

Luria A. The directive function of speech in development and dissolution, part 1. Word. 1959; 15:341–352.

Maess B, Friederici AD, Damian MF, Meyer AS, Levelt WJM. Semantic category interference in overt picture naming: Sharpening current density localization by PCA. Journal of Cognitive Neuroscience. 2002; 14:455–462.10.1162/089892902317361967 [PubMed: 11970804]

Marcovitch S, Boseovski JJ, Knapp RJ. Use it or lose it: Examining preschoolers' difficulty in maintaining and executing a goal. Developmental Science. 2007; 10:559–564.10.1111/j.1467-7687.2007.00611.x [PubMed: 17683342]

Matute E, Rosselli M, Ardila A, Morales G. Verbal and nonverbal fluency in Spanish-speaking children. Developmental Neuropsychology. 2004; 26:647–660.10.1207/s15326942dn2602_7 [PubMed: 15456689]

Morton JB, Trehub SE, Zelazo PD. Sources of inflexibility in 6 year olds' understanding of emotion in speech. Child Development. 2003; 74:1857–1868.10.1046/j.1467-8624.2003.00642.x [PubMed: 14669900]

Munakata Y, Chatham CH, Snyder HR. Developing cognitive control: Three key transitions. Current Directions in Psychological Science. 2012; 21:71–77.10.1177/0963721412436807 [PubMed: 22711982]

Novick JM, Kan I, Trueswell J, Thompson-Schill S. A case for conflict across multiple domains: Memory and language impairments following damage to ventrolateral prefrontal cortex. Cognitive Neuropsychology. 2009; 26:527–567.10.1080/02643290903519367 [PubMed: 20183014]

Riva D, Nichelli F, Devoti M. Developmental aspects of verbal fluency and confrontation naming in children. Brain and Language. 2000; 71:267–284.10.1006/brln.1999.2166 [PubMed: 10716861]

Robert P, Lafont V, Medecin I, Berthet L, Thauby S, Baudu C, Darcourt G. Clustering and switching strategies in verbal fluency tasks: Comparison between schizophrenics and healthy adults. Journal of the International Neuropsychological Society. 1998; 4:539–546.10.1017/S1355617798466025 [PubMed: 10050358]

Robinson G, Shallice T, Cipolotti L. Dynamic aphasia in progressive supranuclear palsy: A deficit in generating a fluent sequence of novel thought. Neuropsychologia. 2006; 44:1344–1360.10.1016/j.neuropsychologia.2006.01.002 [PubMed: 16504225]

Rougier NP, Noelle DC, Braver TS, Cohen JD, O'Reilly RC. Prefrontal cortex and flexible cognitive control: Rules without symbols. Proceedings of the National Academy of Sciences of the United States of America. 2005; 102:7338–7343.10.1073/pnas.0502455102 [PubMed: 15883365]

Rueda MR, Posner MI, Rothbart MK. The development of executive attention: Contributions to the emergence of self-regulation. Developmental Neuropsychology. 2005; 28:573–594.10.1207/s15326942dn2802_2 [PubMed: 16144428]

Sauzéon H, Lestage P, Raboutet C, N'Kaoua B, Claverie B. Verbal fluency output in children aged 7–16 as a function of the production criterion: Qualitative analysis of clustering, switching processes, and semantic network exploitation. Brain and Language. 2004; 89:192–202.10.1016/S0093-934X(03)00367-5 [PubMed: 15010250]

Schnur TT, Schwartz MF, Kimberg DY, Hirshorn E, Coslett HB, Thompson-Schill SL. Localizing interference during naming: Convergent neuroimaging and neuropsychological evidence for the function of Broca's area. Proceedings of the National Academy of Sciences of the United States of America. 2009; 106:322–327.10.1073/pnas.0805874106 [PubMed: 19118194]

Schnur TT, Lee E, Coslett HB, Schwartz MF, Thompson-Schill SL. When lexical selection gets tough, the LIFG gets going: A lesion analysis study of interference during word production. Brain and Language. 2005; 95:12–13.10.1016/j.bandl.2005.07.008

Schnur TT, Schwartz MF, Brecher A, Hodgson C. Semantic interference during blocked-cyclic naming: Evidence from aphasia. Journal of Memory and Language. 2006; 54:199–227.10.1016/j.jml.2005.10.002

Scott RM, Wilshire CE. Lexical competition for production in a case of nonfluent aphasia: Converging evidence from four different tasks. Cognitive Neuropsychology. 2010; 27(6):505–538.10.1080/02643294.2011.598853 [PubMed: 21864200]

Smidts DP, Jacobs R, Anderson VA. The Object Classification Task for Children (OCTC): A measure of concept generation and mental flexibility in early childhood. Developmental Neuropsychology. 2004; 26:385–401.10.1207/s15326942dn2601_2 [PubMed: 15276901]

Snyder HR. Major depressive disorder is associated with broad impairments on neuropsychological measures of executive function: A Meta-analysis and review. Psychological Bulletin. 2012 Online ahead of print. 10.1037/a0028727

Snyder HR, Munakata Y. Becoming self-directed: Abstract representations support endogenous flexibility in children. Cognition. 2010; 116:155–167.10.1016/j.cognition.2010.04.007 [PubMed: 20472227]

Snyder HR, Banich MT, Munakata Y. Choosing our words: Retrieval and selection processes recruit shared neural substrates in left ventrolateral prefrontal cortex. Journal of Cognitive Neuroscience. 2011; 23:3470–3482.10.1162/jocn_a_00023 [PubMed: 21452939]

Snyder HR, Hutchison N, Nyhus E, Curran T, Banich MT, O'Reilly RC, Munakata Y. Neural inhibition enables selection during language processing. Proceedings of the National Academy of Sciences. 2010; 107:16483–16488.10.1073/pnas.1002291107

Snyder HR, Munakata Y. So many options, so little time: The roles of association and competition in underdetermined responding. Psychonomic Bulletin & Review. 2008; 15:1083–1088.10.3758/PBR.15.6.1083 [PubMed: 19001571]

Thompson-Schill SL, D'Esposito M, Aguirre GK, Farah MJ. Role of left inferior prefrontal cortex in retrieval of semantic knowledge: A reevaluation. Proceedings of the National Academy of Sciences of the United States of America. 1997; 94:14792–14797.10.1073/pnas.94.26.14792 [PubMed: 9405692]

Towse JN, Lewis C, Knowles M. When knowledge is not enough: The phenomenon of goal neglect in preschool children. Journal of Experimental Child Psychology. 2007; 96:320–332.10.1016/j.jecp.2006.12.007 [PubMed: 17300798]

Troyer AK, Moscovitch M, Winocur G. Clustering and switching as two components of verbal fluency: Evidence from younger and older healthy adults. Neuropsychology. 1997; 11:138–146.10.1037/0894-4105.11.1.138 [PubMed: 9055277]

Troyer AK, Moscovitch M, Winocur G, Leach L, Freedman Morris. Clustering and switching on verbal fluency tests in Alzheimer's and Parkinson's disease. Journal of the International Neuropsychological Society. 1998; 4:137–143.10.1017/S1355617798001374 [PubMed: 9529823]

Zelazo P. An age-related dissociation between knowing rules and using them. Cognitive Development. 1996; 11:37–63.10.1016/S0885-2014(96)90027-1

- Children often struggle to behave flexibly when they must use self-directed goals.
- Such struggles may reflect the demands of selecting among many potential options.
- Measured children's selection with the blocked cyclic naming task for the first time.
- Children showed robust difficulty in selecting among options.
- Providing subcategory labels to reduce selection demands improved selection.

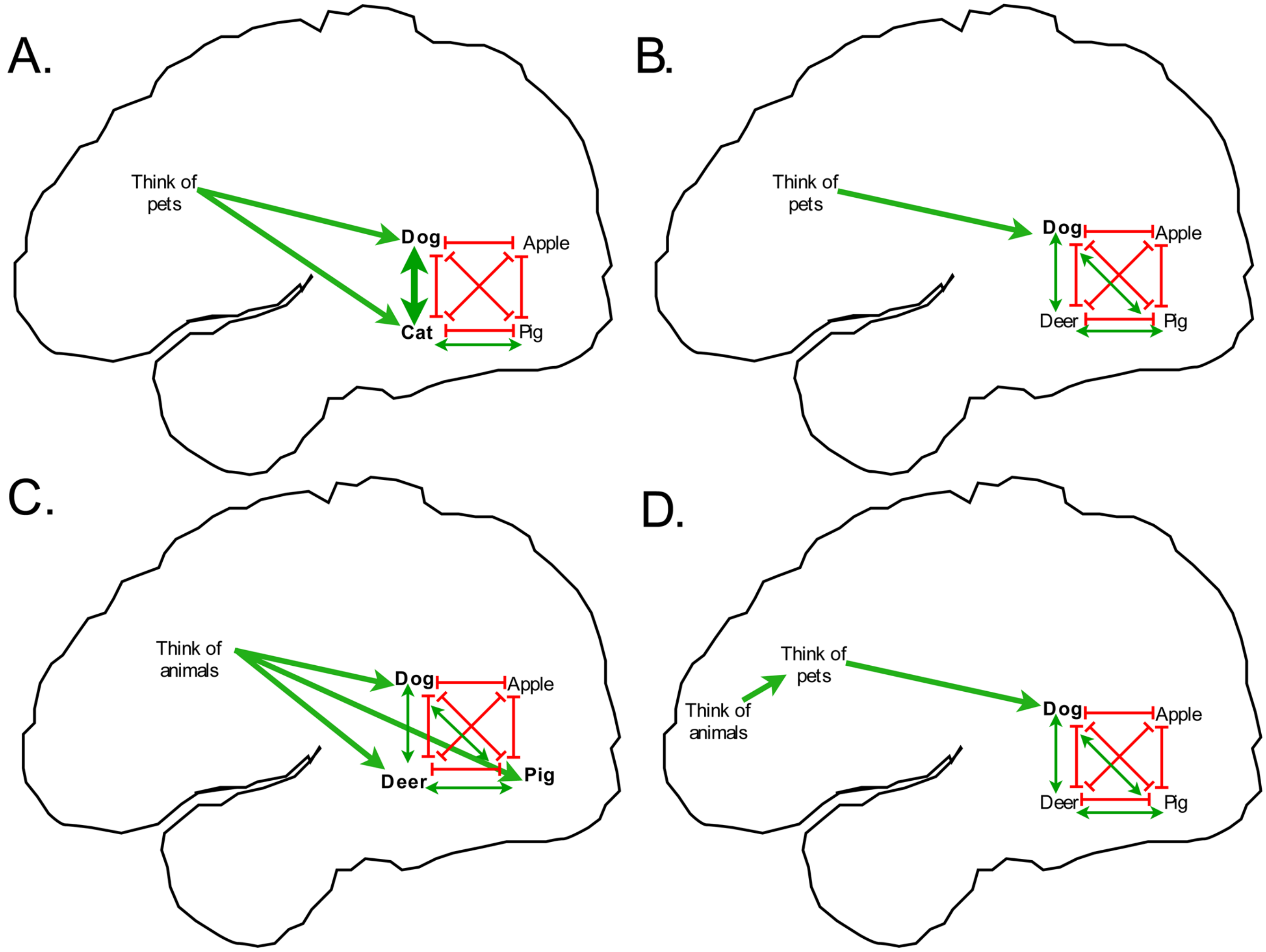

Figure 1.

Illustration of how category labels are posited to affect selection among competing words. This study focuses on testing the behavioral implications of this framework, which is sketched in terms of associated neural regions for illustrative purposes only. Associated representations in posterior cortical semantic networks activate one another via excitatory connections (spreading semantic activation; green double-headed arrows). Goal representations are maintained in working memory and provide top-down support, via excitatory connections from the prefrontal cortex (green single-headed arrows), for relevant options, causing goal-appropriate representations to become more strongly activated (bold words). Representations compete with one another via inhibitory connections (red t-bars), allowing the most active, goal-appropriate representations to win out over alternatives and be selected for production. **(A)** In the verbal fluency task, subcategory labels are hypothesized to activate subcategory representations (e.g., *think of pets* when naming animals), which provide top-down support for a more limited pool of animal items, helping to resolve the competition among the many animal words the child knows. **(B)** In the BCN task, subcategory labels are likewise hypothesized to activate subcategory representations (e.g., *think of pets*) which provide top-down support for the relevant picture (e.g., *dog*) allowing it to overcome competition from other animal names in the block that are coactivated via spreading semantic activation. Superordinate labels could either **(C)** increase competition by activating superordinate representations (e.g., *think of animals*) that provide top-down support for all items in the block, increasing their activation levels and thus competition, or **(D)** decrease competition by indirectly activating subcategory representations (e.g., thinking about how dogs and lions are both animals causes children to then think of how dogs are pets and lions are zoo animals), which then provide top-down support for the relevant picture.

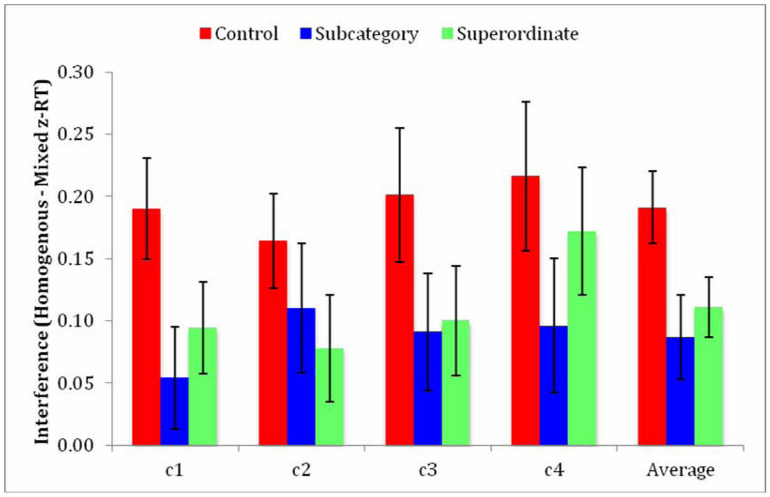

Figure 2.
Children in the subcategory condition had significantly less BCN interference than children in the control condition on average, and this effect did not vary significantly across cycles. Children in the superordinate category condition had less interference than those in the control condition, and did not differ overall from those in the subcategory condition; however, interference increased sharply in cycle 4 for the superordinate condition but not in the subcategory condition. Error bars are the standard error of the mean. c = cycle.

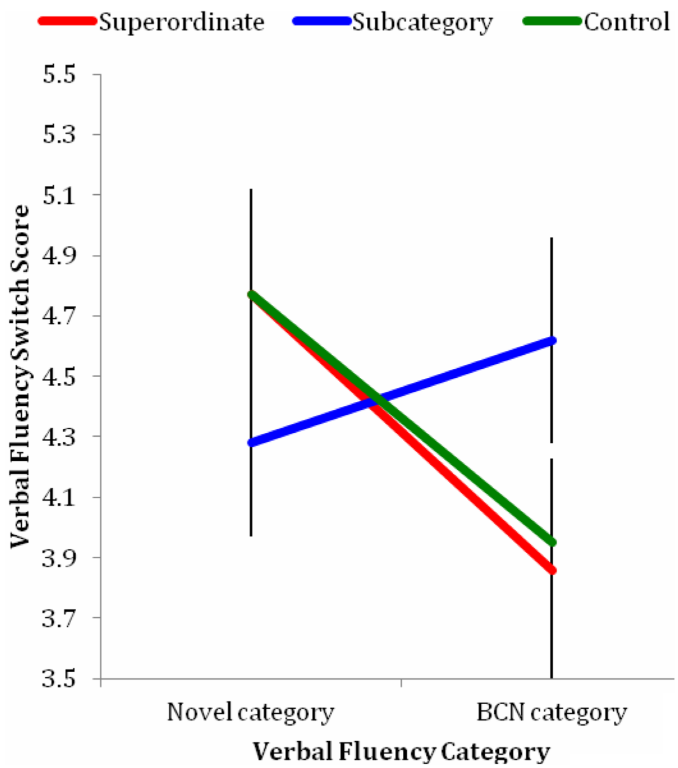

Figure 3.
Transfer from Blocked Cyclic Naming to the verbal fluency task: BCN subcategory information was more effective than BCN superordinate category information in reducing interference in the subsequent verbal fluency task. Interference from BCN is indexed by worse verbal fluency performance with the category experienced during BCN (BCN category) relative to a novel category. Error bars are standard error of the mean.

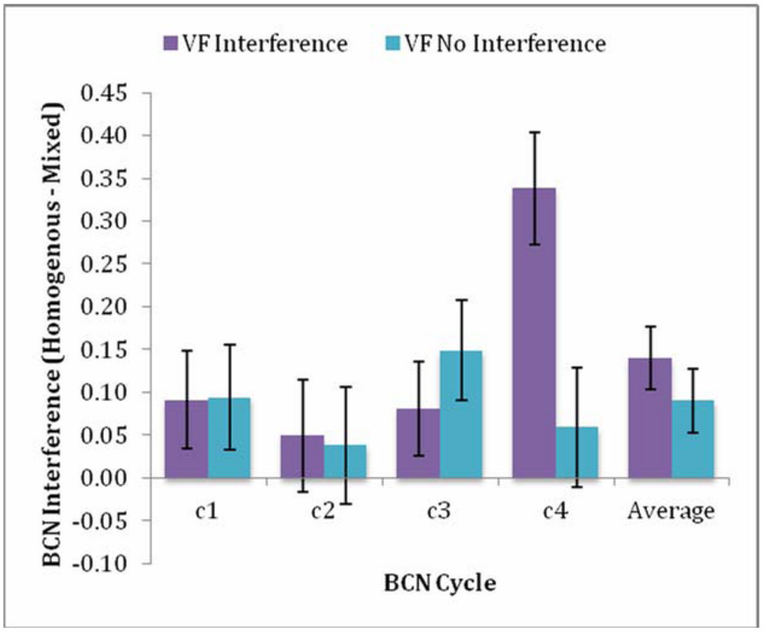

Figure 4.
Children in the superordinate category condition who went on to show interference from BCN during verbal fluency had a sharp increase in BCN interference in cycle 4. Error bars are the standard error of the mean. c = cycle.

Table 1

Interference in the Blocked Cyclic Naming Task

	Cycle	Mean (SD)	*t*	*p*	*d*
Control Condition	1	0.19 (0.25)	4.61	< .001	0.76
	2	0.16 (0.23)	4.28	< .001	0.70
	3	0.20 (0.32)	3.75	.001	0.63
	4	0.22 (0.36)	3.62	.001	0.61
	Average	0.19 (0.18)	6.51	< .001	1.06
Subcategory Condition	1	0.05 (0.25)	1.31	.2	0.20
	2	0.11 (0.32)	2.13	.041	0.34
	3	0.09 (0.29)	1.92	.063	0.31
	4	0.10 (0.33)	1.79	.082	0.30
	Average	0.09 (0.17)	3.04	.004	0.53
Superordinate Condition	1	0.09 (0.24)	2.53	.015	0.38
	2	0.08 (0.27)	1.82	.076	0.30
	3	0.10 (0.28)	2.29	.027	0.36
	4	0.17 (0.33)	3.36	.002	0.52
	Average	0.11 (0.15)	4.65	< .001	0.73

Note. Average interference (homogeneous – mixed zRT) by cycle and condition. Children showed robust interference across all conditions of the Blocked Cyclic Naming Task. ANOVA outliers are excluded for consistency with the following analyses on the effects of BCN condition (results are similar with all participants included). Control condition $df = 35$, subcategory condition $df = 36$, superordinate condition $df = 40$.