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The Effects of Abstract Subcategory Representations on Selection Demands

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Abstract

Selecting the appropriate response to a situation can be difficult for children. We investigated how abstract representations reduce these demands, by introducing subcategories into the Blocked Cyclic Naming (BCN) task. During BCN, participants name objects in two conditions: items from the same category and different categories. Significant naming delays occur in the same-category condition compared to the different-category condition, because activations of similar items in the same category create high competition, resulting in high selection demands when participants name items (Schnur et al., 2006). To introduce abstract representations, we labeled items on the exemplar and subcategory levels. Results showed a trend for children given subcategory labels to have improved selection, suggesting that the abstract representations reduced selection demands. In summary, selection plays a major role in daily life and the current study suggests that abstract representations may be able to help us understand the mechanism behind the selection process.

Introduction

Naming objects is a seemingly mindless task. We do it all day, everyday; but we do not realize the work our brains must do to choose the word we want to say. We overcome competition between all other words we think of to select the appropriate word (e.g., a parent having all of their children's names come to mind and having to select the appropriate name). Selection requires cognitive control, which is the ability to voluntarily guide one's behavior. Cognitive control is not fully developed until adulthood, enabling adults to perform harder selection tasks than children (e.g. Friedman, Nessler, Cycowicz, & Horton 2009; Luna, Padmanabhan, & O'Hearn, 2010). Choosing the appropriate response is more difficult for children because their prefrontal cortexes (which are thought to be the seat of cognitive control) are underdeveloped (e.g. Diamond, 2002; Thompson-Schill, D'Esposito, Aguirre, & Farah, 1997). This prevents them from performing as well on selection tasks as adults. The current study explores how selection mechanisms develop by attempting to improve the selection deficits that children face. In this study, we attempt to improve selection in young children by providing abstract subcategory labels during a selection task.

To understand how selection works, we must first understand how all the things we have to select from are organized in the brain. Our brains sort items into a limited number of categories to simplify the world around us and to help us to interpret new objects (Verbeemen, Vanpaemel, Pattyn, Storms, & Verguts, 2007). This organization, called the semantic space, is structure similarly in most humans (Rosch, E., 1975). For example, most humans develop an organization of animals by habitat or environment when they are children and maintain this organization throughout life (Crowe & Prescott,

2003). To select an object, we must retrieve it from semantic storage, or search space. Our brains must sift through all the semantically similarly stored objects to retrieve the correct word. Although we do not know yet how to improve cognitive control and selection in children, there is some evidence that the way the semantic search space is organized may be the key. Constraining the semantic search space, by temporarily altering how objects are represented, may make it easier to access target words (Snyder & Munakata, 2010).

The way our brains categorize items directly effects selection. Items from the same category are semantically similar, and interfere with one another. This categorization into superordinate semantic categories has been shown to be a disadvantage in word selection tasks. Semantic interference during selection is evident in many selection tasks covering a broad spectrum of semantic relationships between items. In one selection task, naming an item in a category primes the subsequent naming of the same item; however, it interferes with the subsequent naming of a different item in the same category (Oppenheim, Dell, & Schwartz, 2010; Damian & Als, 2005). In other tasks, objects are named slower when another semantically related object is presented at the same time compared to when an unrelated item is presented (Schriefers, Meyer, & Evelt, 1990). Further, other studies have found that semantic interference in naming can occur not only in categorically related object tasks, but also when items are related but from different semantic categories (e.g. “bee,” “honey,” “beekeeper”) (Rahman & Melinger, 2007). Lastly, a final set of studies showed that objects from categories where many of the exemplars are structurally similar (e.g. *animals*) take longer to be named than do objects from categories in which the exemplars are structurally distinct (e.g.

appliances) (e.g. Lloyd-Jones & Humphreys, 1997; Price & Humphreys, 1989). Semantic interference occurred in all of these studies. Therefore, to improve performance on these tasks, and other selection tasks, an intervention must occur to reduce interference. The fact that the semantic category of words interferes with retrieval in many different studies leads us to posit that altering how objects are presented in semantic categories could improve performance on related object naming selection tasks.

Manipulating the abstract representations may activate certain categorical structures. Abstract representations play a part in simplifying mental space by removing irrelevant information. They encompass sets of lower-level instances, coding for the shared features of the members of the group while generalizing over all the irrelevant variance within the subcategory (e.g. Son, Smith, & Goldstone, 2008). For example, an abstract label like *dessert food* will encompass all lower level dessert foods: *cookie*, *cake*, *ice cream*, etc. In the current study we induce abstract representations by introducing subcategory labels. Therefore, the process of providing subcategory labels may induce a sub-categorical, abstract representation of the task space (e.g. *dessert* to label a picture of *cake* within the *food* category). When provided, subcategory labels (e.g. *dessert*, *fruit*, *lunch*, *vegetable*, *breakfast*, and *snack food* within the food category) may constrain the semantic space to just subcategory names instead of all possible items in that category (e.g., *food*). This could limit the number of competing items (e.g. *sandwich*, *apple*, *carrot* and other non-dessert *foods*) recalled when the person sees a picture (e.g. *cake*), enabling the person to correctly identify the picture more quickly.

In a previous study using a task that involved both switching and selection, it was found that manipulating abstract representations, via subcategory labels, improved

children's performance. This task, verbal fluency (VF) requires children to generate as many words as they can in one minute from a category. To perform maximally, children need to cluster (produce words within semantic subcategories) and switch (shift between subcategories). In addition, children need to detect when to switch (e.g. when they cannot retrieve any more items from a subcategory) and select what to switch to. Providing children with subcategory labels (e.g. ocean animals) before the task limits the number of competing items from all of the category members (e.g. all *animals*) to a smaller pool of subcategory members (e.g. the 10 ocean animals the child knows) when generating words within clusters. Children provided with subcategory labels in the VF task produced more words and switched more than those who were provided with an exemplar of a category member (Snyder & Munakata, 2010). Subcategory labels designed to induce abstract categorical representations might reduce selection demands, but it is unclear if improvement in VF performance is due to a reduction in selection demands or if switching demands were eased. For this reason, we chose a task for the current study that eliminates switching without sacrificing high selection demands. Findings from Snyder and Munakata (2010) lead us to believe that subcategory labels will aid other selection tasks, which do not involve switching demands, by inducing abstract representations of the task.

In the current study, the Blocked Cyclic Naming (BCN) task is used to directly study how abstract representations reduce selection demands. The task provides a measure of selection without interference from switching. In the task, participants name objects in two different conditions: homogenous and mixed blocks. In the homogenous block, items from the same category are presented (e.g. *cookie, apple, cake, and carrot*

for *Food*). Contrastingly, in the mixed block items are presented from different categories (e.g. *car*, *cookie*, *pants*, and *bench*). In both adult aphasic and normal speakers, naming latencies are longer and errors occur significantly more often in homogenous blocks than in mixed blocks (Schnur, Schwartz, Brecher, & Hodgson, 2006). Further, the errors occurring in homogenous blocks are almost always semantically related to the target word in the trial (Hsiao, Schwartz, Schnur, & Dell, 2009, & Schnur et al., 2009). The longer reaction time in the homogenous blocks compared to the mixed blocks is called a semantic blocking effect and has been shown to grow within each homogenous block as the pictures repeat (4 times or *cycles*). This is caused by the activation of all items within the category, because as multiple items are activated (competition between items is high) it becomes harder to select the target. To explore the effect of abstract representations on the BCN semantic blocking effect, we manipulate the kind of labels we give to pictures in the task (subcategorical or exemplar label only). We predict that by giving each picture a different subcategory label (e.g. *pet animal*, *zoo animal*, *etc* for *animals*), we can induce an abstract representation of the task in the child's brain. This abstract representation of the task would activate the mental organization using their subcategory and not their broader category, preventing all non-subcategory members from being recalled when a particular picture is shown and therefore reducing interference. The exemplar label (e.g. *lion*) condition acts as a comparison to see if the use of the subcategory labels lessens the semantic blocking effect. The exemplar labels simply name each item, which should not have an effect on selection demands.

In summary, we are using the BCN task to determine whether the benefit of abstract representations on performance in the verbal fluency task (Snyder & Munakata,

2010) may be driven by reduction in selection demands. If the increased performance found when using abstract representations is in fact driven by reduced selection demands, then the abstract representations should have the same effect in the BCN task as in the verbal fluency task. In particular, abstract representations should lessen the semantic blocking effect. We expect that using subcategory labels will reduce selection demands, leading to a decreased semantic blocking effect compared to using exemplar labels.

Method

Participants

Twenty-eight 71- to 81-month-olds participated ($M=77.1$; range 73-80.9; 11 girls). Eleven participants were excluded from analysis due to fussiness (6), parental interruption (1), inability to remember words (2), and failure to complete at least 4 blocks in each category (2). Participants were recruited from a database of families who voluntarily participate in research. Parents gave informed consent (including a video release) according to procedures approved by the University of Colorado Institutional Review Board. Parents were paid \$5 for travel expenses and children received a small prize for participating, in addition to stickers as needed to motivate them throughout the procedure. Parents were debriefed on the research purposes after the session and were informed of the findings in a yearly newsletter.

Blocked Cyclic Naming (BCN)

Stimuli and Design.

Thirty-six colored pictures were the stimuli for the BCN task. The pictures were of familiar items (e.g. *table*, *lion*, *dress*, *airplane*, *crayon*, and *toaster* (Morrison, Chappel, & Ellis, 1997)) from six categories (*vehicles*, *furniture*, *appliances*, *toys*,

clothing, and either *animals* or *food*). The pictures were arranged in blocks of six pictures. There were six homogenous blocks (all pictures came from the same category) and six mixed blocks (one picture from each category) for a total of 12 blocks. The same pictures occurred in both the homogenous and mixed blocks. The two kinds of blocks were presented in an alternating order.

Procedure.

Children were tested in a quiet room, with their parent present, during a single session taking approximately an hour. In each block, participants first completed a familiarization phase (to ensure the children knew the names of pictures and to manipulate the type of label the child received as described further in the next paragraph) with the six items of the block on a printout. To begin, the experimenter said, “We are going to play a naming game. I bet you know lots of names of things, don’t you? I’ll show you some pictures and I want you to tell me what they are, OK?” The experimenter pointed to each picture and asked, “Can you tell me what this is?” The child then told the experimenter what they believed was the name of the picture.

Each participant was assigned to one of two conditions for this familiarization phase to see if the use of abstract representations (subcategory condition) reduces selection demands and therefore decreases the size of the blocking effect. In the exemplar label condition, if the child was correct in naming the object, the child heard the name of the picture in confirmation that they were correct (e.g. “Yes, that’s an apple. It’s a picture of an apple”). If the child incorrectly named a picture the experimenter said, “Good guess, but that’s an apple, it’s a picture of a apple.” In the subcategory label

condition, the child heard the subcategory of picture (e.g. “Yes, that’s an apple. An apple is a fruit.” or “Good guess, but that’s an apple. An apple is a fruit.”)

After the familiarization phase, the child completed the experimental phase on the computer. 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!” At the beginning of each trial a chime sounded, followed by a 500ms blank screen, and then the picture appeared in the center of the screen. The picture remained on the screen until the child began to name the picture, at which point the experimenter pushed a button to record the child’s reaction time, triggering the beginning of the next trial. In each block, the six pictures were presented four times (cycles) in a random order with the same picture never occurring twice in a row. Children completed 12 blocks. The whole session was recorded using a digital camera and a digital recorder to verify the experimenter’s accuracy in recording the reaction time.

Analysis.

The mean reaction time and standard deviation for mixed and homogenous blocks were calculated. All blocks in which the child incorrectly identified a picture during the familiarization phase were excluded from analysis. All blocks in which the child was fussy, talking about other topics or clearly not looking at the screen, were excluded. On average, 1.68 blocks were excluded per child. In addition, any reaction time that was greater than 5 seconds, less than 200 ms, or greater than the mean of all the reaction times $\pm$ three standard deviations was excluded from analysis. After trimming, the mean across all homogenous blocks was taken for each of the 4 cycles and again across all

mixed blocks for each cycle. To calculate the blocking effect, the mean for each mixed cycle was subtracted from each corresponding homogenous cycle mean (e.g. the mean reaction time from the 2nd homogenous cycle is subtracted from the mean reaction time from the 2nd mixed cycle).

Verbal Fluency Task (VF)

Procedure.

The VF task was included in testing to see if there was a relationship between performance on BCN and the VF task, as both have high selection demands. Although VF performance has been improved by abstract representations in past research, BCN had yet to be tested. During the task, children had to name as many items from a given category as they could. Each child first completed a practice semantic category (e.g., things in a house) followed by two categories (animals and foods). The child had 1 minute per category. To begin, the child was presented with the task as a game, “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 the sand is all gone. I’ll bet you can get a lot! When we are all done thinking of words, you can trade in your pompom for stickers.” A one-minute sand-timer was used to help the children to stay on task. Before the child began each category the experimenter said, “Okay, this time I want you to tell me as many [category] as you can think of. Can you think of lots of lots of [category]? Ready, set, go!” If the child paused for more than 10 seconds during the task they were prompted, “good job, can you tell me some more [category]?”

Analysis.

Data was transcribed from digital audio recordings. The experimenter and two other raters who were blind to condition coded the data. Coders identified clusters of semantically related items (e.g. “seal, dolphin, shark” in *animals* category). A weighted switch score was calculated as follows: one point was awarded for each switch after two related items, two points for a switch after three related items, and so forth. The weighted switch score reflects true clustering and switching when cluster size increases (Snyder & Munakata, 2010). The switch score was averaged across all raters along with the rater’s raw count of non-repeated words.

Expressive Vocabulary Test (EVT)

The Expressive Vocabulary Test (EVT) (Pearson Assessments, Bloomington, MN) was used to provide a valid and reliable measure of verbal ability. Controlling for verbal ability ensured that any relationship between BCN and VF was not driven merely by verbal ability, since they are both verbal tasks. The EVT is a standardized, nationally normed, expressive vocabulary assessment. During the task, the child was shown colored pictures, and was asked to name them or provide synonyms based (e.g. “Can you tell me another word for evening?”). Testing continued until the child reached their ceiling (five incorrect answers in a row). Raw scores were then converted into a percentile score based on age.

Results

Semantic Blocking Effect

First, we found a semantic blocking effect such that naming was delayed in homogenous versus mixed blocks, in the average of all cycles, $t(27) = 3.85$, $p < .001$. In

addition, there was a trend towards larger semantic blocking effects in the exemplar condition than in the subcategory condition in cycle 3 (see Table 1 and Figure 2).

However, in the first cycle, there was a trend for the blocking effect to be higher in the subcategory condition than in the exemplar condition. This was presumably because there should not be any build up of interference during the first cycle. For this reason, only the last three cycles were used to calculate the average blocking effect, which also followed the trend and was greater in the exemplar condition than in the subcategory condition.

None of these trends reached significance (see Table 3).

	Exemplar		Subcategory	
	Mean	Standard Deviation	Mean	Standard Deviation
Blocking Effect Cycle 1	36.29	116.63	70.24	80.83
Blocking Effect Cycle 2	71.25	141.49	31.88	136.55
Blocking Effect Cycle 3	138.09	148.99	29.10	142.27
Blocking Effect Cycle 4	68.85	124.16	46.54	193.40
Average Blocking Effect (Cycles 2-4)	92.15	109.22	37.57	103.08
EVT Percentile	82.21	14.47	74.07	15.37
Average VF Switch Score	4.23	1.70	3.49	1.31
Average Total VF Words	10.89	3.07	10.39	2.48
Age	77.26	3.04	77.01	2.64

Table 1. Blocking Effect, EVT score, VF score, and age descriptive statistics for participants in the subcategory and exemplar conditions. Subcategory condition participants generally had smaller blocking effects in cycles 2-4, but a larger blocking effect in cycle 1 when compared to exemplar condition participants. Age was closely matched for both conditions. Participants in the exemplar condition generally score higher on the EVT task. Although exemplar condition participants scored slightly higher on both VF measures, the difference was minimal.

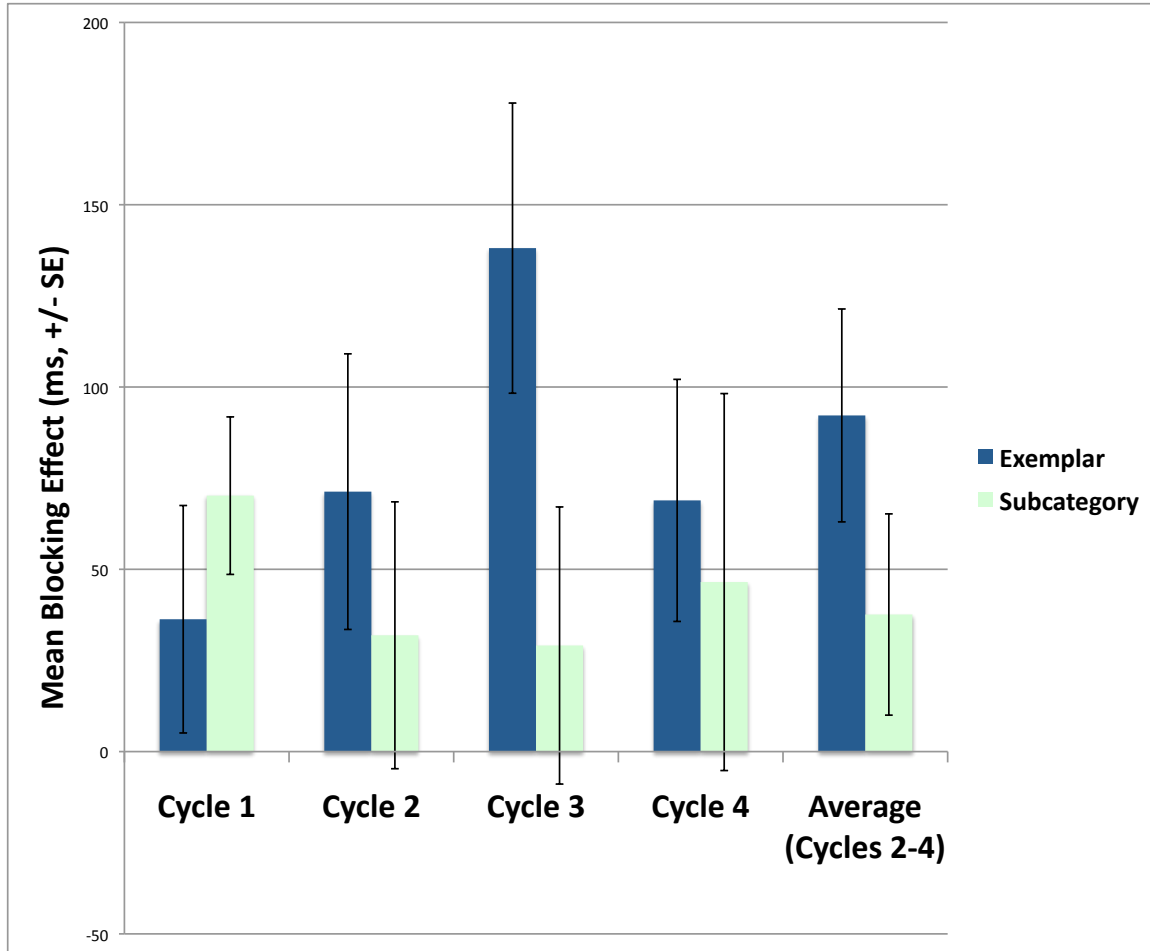


Figure 2. Blocking Effect for each cycle across conditions. For cycles 2-4 and for the average across those cycles, the subcategory condition participants generally had lower blocking effects than the exemplar condition participants.

	t	df	Sig. (2-tailed)
Blocking Effect Cycle 1	-0.89	26	.379
Blocking Effect Cycle 2	0.75	26	.461
Blocking Effect Cycle 3	1.98	26	.058
Blocking Effect Cycle 4	0.36	26	.719
Average Blocking Effect (Cycles 2-4)	1.36	26	.186

Table 3. Independent samples t-test results for blocking effects per cycle across conditions.

EVT

There was a non-significant trend towards a difference in EVT percentile scores between the exemplar and subcategory conditions, $t(26) = 1.44$, $p=0.16$. The participants

in the exemplar condition scored higher on the EVT test compared to the subcategory participants. Since participants in the subcategory condition had lower EVT scores, superior verbal ability could not be driving the smaller blocking effects found in that group.

Verbal Fluency

There was no significant difference between conditions in switching scores, $t(26) = 1.29, p = 0.21$, or total words produced, $t(26) = 0.47, p = 0.64$. Therefore, the effect of providing subcategory labels in the BCN task did not carry over into the VF task.

Discussion

The results provide some support for our prediction that children who were given subcategory names of objects would have improved selection compared to those who are only told the name of the object. There was a trend for children who were given subcategory names to have smaller blocking effects for cycle 3 and the average across cycles 2-4, but not for cycle 1. This finding regarding cycle 1 is not surprising as the first cycle is the first time the children have to name the items in the block, so there should be minimal build up of activation and therefore minimal interference. Decreased blocking effects in cycle 3 and the average of cycles 2-4 in the subcategory condition supported our prediction that subcategory names would decrease the semantic blocking effect. We believe that the subcategory names may have reduced interference between category members and therefore made it easier to name pictures in the same category. We also found that despite the fact that EVT scores were lower in the subcategory condition, the

blocking effects were smaller for these participants. This difference in EVT scores between groups would only have been a confound had the EVT scores been higher for those in the subcategory condition, because then we could also attribute the decrease in blocking effects to more advanced vocabularies. However, since those in the subcategory label condition showed less advanced vocabularies the smaller blocking effects in that condition cannot be attributed to better verbal ability. Lastly, we found that providing subcategory names to participants in the BCN tasks did not increase performance in the VF task. In the previous study, abstract representations were presented via subcategory labels during the VF task itself (Snyder & Munakata, 2010). In this study, we looked for carry-over effects, as the subcategory labels were presented during the BCN task. Even though abstract categorical representations, via subcategory names, aided performance on the VF task in the past, they did not help in the current study. One explanation may be that even though the abstract representations helped on the task they were presented during, the child forgot about the subcategories before the next task. This means that if we were ever to implement abstract representations in the real world, we would have to be constantly reminding and cueing children.

Overall, our findings support previous research. First, we found a semantic blocking effect in all cycles, such that naming was delayed in homogenous versus mixed blocks (Schnur et al, 2006). This study was the first to show this effect in children using the modified task adapted for children. Additionally, past research on the VF task, which involves switching and selection, found that presenting children with subcategory labels before the task improved switching scores and total word production (Snyder & Munakata, 2010). This improvement was also found in BCN, a selection task that did not

involve switching. Since subcategory labels helped performance on both selection tasks we believe they may aid performance by reducing selection demands. This helps to interpret the findings of the previous study as more likely due to reduced selection demands, not switching demands.

There were some limitations to our study that lowered the power of our results. First, we were only able to keep 14 children in each condition. If we were able to run more children in each condition, the results would become cleaner. Secondly, the recording mechanism for the reaction time in the BCN task was the experimenter pressing a button after the child began answering the question. This may have introduced error because the experimenter may have been inconsistent. We did not analyze the accuracy of reaction time recording by the experimenter, however the data will be analyzed in the future to see how reliable the experimenter was in pushing the button after voice onset time. Lastly, there was a discrepancy in EVT scores across conditions. This difference occurred by chance despite random assignment to conditions. However, when more participants are run in the future it will be possible to control for EVT scores. All of the study's limitations could be easily addressed by voice onset time analysis and the addition of more subjects.

A delimitation of the study was the variety of categories that the BCN objects belonged to. There are some categories, like animals, that seem more likely to be stored together in the mental semantic space (Crowe & Prescott, 2003). Other categories, like appliances and furniture, may be easily associated within category, as we assumed, or within environment (e.g. "tv" and "couch" may be as semantically related, or more, than "iron" and "tv"). Categories like animals and foods are therefore potentially more

semantically related. Since these categories are more semantically related, there may be more interference within the category. Subcategory labels may have a more salient effect on these categories because they have more interference to overcome. Eliminating categories of objects that may not be stored together in semantic space may strengthen the effect. We chose to include all 6 categories in analyses, however it may be interesting to consider running the task in the future using only the categories that have strong semantic relationships.

Our findings regarding abstract representations add to a growing body of research about semantic blocking and how it relates to selection. In addition to showing the semantic blocking effect, our results indicate a way to minimize the effect. Minimizing the effect, via subcategory labels, helps us to understand the underlying mechanism to selection, as the effect is a reflection of the general property of the semantic system (Belke, Meyer, & Damian, 2005). Past research has shown that the mental search space is organized semantically and that this organization creates a problem. When we are forced to select items in rapid succession from within a category, all the other members of the category interfere. However, when we are able to constrict the semantic search space using subcategories rather than category names, the interference dissipates.

Figuring out how to dissipate this interference has several implications for future research. First, we would like to add a superordinate category label condition (e.g. apple is a “food”). This condition involves manipulating the categorical abstract representation of the task. However this organization, being broader, should not help performance. This is because unlike subcategory labels, which constrict the semantic search space to one subcategory, superordinate labels broaden the search space. They restructure the search

space to include all items of a category including those that were not presented, but may be the participant's favorite or best exemplar. We predict the participants in this condition would perform very similarly to those in the exemplar label condition, or possibly even worse.

Further, we need to use abstract representations in other tasks to see if using subcategory labels is actually constricting search space, or if they are helping a different aspect of the tasks. We need to study more tasks that require selection, like BCN, and those that solely use switching. This may help us to understand what mechanisms are affected when abstract representations are altered.

Additionally, many of the studies preceding ours examined the semantic blocking effect in patients with Broca's aphasia. This type of aphasia is characterized by damage in the left inferior frontal gyrus, or "Broca's area" and a landmark loss in speech fluency (Damasio, 1992). These patients have particularly strong semantic blocking effects because the mechanism thought to bias selection when demands are high resides in the left inferior prefrontal cortex (Schnur et al, 2006; Thomas-Schill et al., 1997). Providing them with subcategory names during the task may be able to improve their performance, but it may also be able to help with everyday tasks. For example, many stroke patients have a hard time finding the word they wish to say. Providing more specific cues may help them to find their target word quicker. In the same way, children struggling in semantic development, often over extending one word to refer to all words that are semantically related, may also benefit from subcategory cues. Children often use language in a way that one word encompasses many concepts that adults have more words for (e.g. a child calling all four legged animals *dog* even though they are familiar

with other animals) (Clark, 1973). Explaining to children that certain words (e.g. *dog*) only occur in certain contexts (e.g. as a pet animal) may help them to differentiate meaning next time and select the correct word (e.g. *bear* in the *forest*). In summary, investigating selection mechanisms will not only help us to understand how children's minds develop, such as learning new words in childhood, it may also help us to understand how to overcome some of the challenges of recovering from brain injuries.

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