Behavioural Brain Research 287 (2015) 285–293

Contents lists available at ScienceDirect

Behavioural Brain Research

journal homepage: www.elsevier.com/locate/bbr

Research report

Effects of age on cognitive control during semantic categorization

Raksha A. Mudar[a,b,*], Hsueh-Sheng Chiang[b], Mandy J. Maguire[b], Jeffrey S. Spence[b], Justin Eroh[b], Michael A. Kraut[c], John Hart Jr.[b]

[a] Department of Speech and Hearing Science, University of Illinois at Urbana-Champaign, 901 South Sixth Street, Champaign, IL 61820, USA
[b] Center for BrainHealth, The University of Texas at Dallas, 2200 West Mockingbird Lane, Dallas, TX 75235, USA
[c] Department of Radiology, The Johns Hopkins University School of Medicine, 601 North Caroline Street, Baltimore, MD 21287, USA

HIGHLIGHTS

- We studied age effects on cognitive control during semantic categorization.
- Examined ERPs related to two visual go/nogo tasks that varied in categorization levels.
- Nogo-N2 and nogo-P3 amplitudes were reduced in older compared to younger adults.
- N2 latency showed differential age effects of categorization.

ARTICLE INFO

Article history:
Received 7 October 2014
Received in revised form 6 March 2015
Accepted 22 March 2015
Available online 28 March 2015

Keywords:
Semantic
Categorization
Cognitive control
Aging
Event-related potentials

ABSTRACT

We used event-related potentials (ERPs) to study age effects of perceptual (basic-level) vs. perceptual-semantic (superordinate-level) categorization on cognitive control using the go/nogo paradigm. Twenty-two younger (11 M; 21 ± 2.2 years) and 22 older adults (9 M; 63 ± 5.8 years) completed two visual go/nogo tasks. In the single-car task (SiC) (basic), go/nogo responses were made based on single exemplars of a car (go) and a dog (nogo). In the object animal task (ObA) (superordinate), responses were based on multiple exemplars of objects (go) and animals (nogo). Each task consisted of 200 trials: 160 (80%) 'go' trials that required a response through button pressing and 40 (20%) 'nogo' trials that required inhibition/withholding of a response. ERP data revealed significantly reduced nogo-N2 and nogo-P3 amplitudes in older compared to younger adults, whereas go-N2 and go-P3 amplitudes were comparable in both groups during both categorization tasks. Although the effects of categorization levels on behavioral data and P3 measures were similar in both groups with longer response times, lower accuracy scores, longer P3 latencies, and lower P3 amplitudes in ObA compared to SiC, N2 latency revealed age group differences moderated by the task. Older adults had longer N2 latency for ObA compared to SiC, in contrast, younger adults showed no N2 latency difference between SiC and ObA. Overall, these findings suggest that age differentially affects neural processing related to cognitive control during semantic categorization. Furthermore, in older adults, unlike in younger adults, levels of categorization modulate neural processing related to cognitive control even at the early stages (N2).

Published by Elsevier B.V.

1. Introduction

Categorization (e.g., categorizing items as animate vs. inanimate) is a basic cognitive skill that allows meaningful organization of objects in our surrounding environment [1–4]. Broadly speaking, objects can be categorized at three levels: basic, superordinate, and subordinate [5]. For example, a 'dog' at the basic level can be categorized at the superordinate level as an 'animal' and at the subordinate level as a 'golden retriever'. Basic and superordinate categorizations are frequently used in day-to-day functioning, whereas subordinate categorization is more specific and relates to in-depth/expert knowledge (e.g., knowledge used by dog experts, car experts, bird experts).

It is well recognized that categorization of object information enhances memory retention and recall in both younger and older adults [1,6,7]. Less well understood is how object categorization influences other cognitive processes such as those related to response inhibition, response conflict, and response monitor-

* Corresponding author at: Department of Speech and Hearing Science, University of Illinois at Urbana-Champaign, 901, S. Sixth Street, Champaign, IL 61820, USA. Tel.: +1 217 333 4718; fax: +1 217 244 2235.
E-mail address: raksha@illinois.edu (R.A. Mudar).

http://dx.doi.org/10.1016/j.bbr.2015.03.042
0166-4328/Published by Elsevier B.V.

ing that fall into the broad concept of cognitive control [8–10]. The ability to successfully withhold/block a pre-potent/dominant tendency to respond is one of the core functions of cognitive control [10], which often involves conflict monitoring and outcome monitoring to an extent. For instance, when walking down a street, we stop if we see an approaching car but continue to walk if we simply see other people walking around. Similarly, when shopping at a grocery store in the produce section, we stop when we see an item on our grocery list (e.g., apples). As we navigate our ever-changing environment, we monitor conflicts between current actions and intentions when competing sources of information are present and withhold our ongoing behavioral responses as needed, and many of these decisions are made based on how objects we encounter are categorized. While there is some evidence in children (7–8 and 10–11 years old) and in young adults (18–31 years old) that basic and superordinate object categorizations differentially affect processing related to response inhibition/conflict [11–13], little is known about how levels of categorization interact with cognitive control in normal older adults (55 years and older). Given the general consensus that aging impacts cognitive control to variable degrees [14–12], examining the effects of object categorization on cognitive control in older adults will provide useful information about how these operations interact and change with age.

Object categorizations at basic and superordinate levels have varying perceptual and semantic processing requirements. Research has shown that basic categorization depends heavily on perceptual information [21–24], whereas superordinate categorization depends on both perceptual and semantic information related to object knowledge [22,23,25–27]. More specifically, basic-level visual object categorization depends on global, coarse perceptual discrimination [21], given that members within the same basic-level category share many perceptual features (e.g., different breeds of dogs), whereas members from different basic-level categories (e.g., dogs vs. cars; dogs vs. birds) share fewer perceptual features. In comparison to basic categorization, superordinate categorization extends beyond perceptual similarities since members of the same superordinate category share relatively few perceptual features, and is conceptually more complex. For instance, the category 'animal' includes perceptually different entities such as a snake and a dog. Thus, categorization at this level depends heavily on semantic information beyond basic perceptual processing [12,23] and involves additional neural resources as have been shown in fMRI studies [28,29].

Following Rosch et al.'s (1976) seminal study, basic-level categorization during tasks that involve overt response selection has been shown by many to be the fastest and most accurate for typical objects [25,27,30–32] with some exceptions. These exceptions include ultra-rapid stimulus exposure (stimulus duration less than 30 ms) and paradigms that incorporate time pressure (i.e., requiring responses to be made within certain reaction time deadlines), which demonstrate faster superordinate categorization than perceptual/basic-level categorization [33–36]. However, we know little about how varying levels of semantic categorization (basic vs. superordinate) affect the ability to withhold/regulate responses, especially in older adults.

In the aging literature, cognitive control processes related to response inhibition, and response conflict have been examined using a variety of paradigms [17,37] such as stroop, negative priming, and go/nogo. This paper focuses on the study of cognitive control using the go/nogo paradigm. The standard go/nogo task requires individuals to respond to a certain type of stimuli (go) and inhibit/refrain from responding to another type of stimuli (nogo), predefined by a specific set of rules and criteria. The accuracy data, i.e. commission errors during nogo trials, in particular, are indicative of the efficiency of cognitive control, but the neural underpinnings of cognitive control may not be directly associated with the behavioral measure [38]. Objective techniques such as electroencephalography (EEG) have therefore been applied to explore neural mechanisms underlying cognitive control (e.g., [37]). Go/nogo tasks, in particular, elicit predictable changes in known event-related potential (ERP) components that are considered to be markers of response inhibition and/or response conflict and response monitoring [39] and are thus useful for studying age-related changes in cognitive control during semantic categorization.

The ERP literature on cognitive control in normal older adults using the go/nogo task is vast, but the majority has examined perceptual discrimination using stimuli such as numbers, letters, shapes, and natural images [13,38,40–43] ([6,36,44] for some exceptions). These go/nogo studies bear close resemblance to basic-level semantic categorization that involves visual processing and discrimination (e.g., discriminating cars from dogs; cars from birds). In these go/nogo studies, two major ERP components have been consistently found. The first component is a fronto-central negative deflection developing between 200 and 400 ms post-stimulus onset (N2) and the second is a subsequent centro-parietal positive deflection (P3) between 300 and 600 ms [41,45–48]. The negative deflection (N2) in the frontal electrodes is considered to be a marker of response inhibition by some [49] (also see [50] for a review), whereas others have suggested its role in conflict monitoring [51–53]. The positive deflection (P3) is considered to be an index of evaluation of stimuli and attentional allocation by some [54,55], while others have suggested its role in response monitoring, be it a decision to respond during go trials or to withhold responses during nogo trials [41]. While the exact functional significance of each of these two ERP components in relation to cognitive control continues to be debated, there is a general consensus that both are markers of cognitive control to some degree [56,57].

Overall, consistent patterns of delayed latency and reduced amplitude in nogo-N2 have been observed in older adults compared to younger adults [40,58], supporting weakening of neural processing related to cognitive control with age. For nogo-P3 latency, the typical finding in studies involving older adults is prolonged latency [42,45,58,59]. The findings of nogo-P3 amplitude have been less consistent, varying from reduced nogo-P3 amplitude [59] to either no age-related differences [58] or increased nogo-P3 amplitude in older compared to younger adults [43]. While these findings provide some indications of age-related alterations in cognitive control that can be expected during basic categorization, it is unclear whether the need to use perceptual and semantic processes for superordinate categorization will aid or impede cognitive control processes in older adults, especially given the predilection toward meaning-based processing of information with age [60].

Two previous ERP studies by Maguire et al. [11,12], one including young adults and the other including children, have examined the effects of varying levels of visual object categorization on cognitive control in typically developing normal populations. In these studies, participants completed go/nogo tasks that compared perceptual (basic) vs. perceptual-semantic (superordinate) categorization. In the young adults study, they found no significant amplitude differences in nogo-N2 between basic and superordinate conditions, whereas nogo-P3 had smaller amplitude for superordinate compared to basic categorization [12]. In the study of children, they compared the performance of 7–8-year olds to that of 10–11-year olds. They found that similar to young adults, 10–11-year olds had smaller nogo-P3 amplitude for superordinate categorization compared to basic categorization, whereas the 7–8-year olds showed no differences. To gain insights into the effects of categorization on cognitive control in later adulthood, we examined known neural markers related to cognitive control (the N2 and the P3 ERPs) in cognitively normal younger and older adults corresponding to two visual go/nogo tasks that have been previously