Journal of Cognitive Psychology, in press

Are go/no-go tasks preferable to two-choice tasks in response time experiments with older adults?

Manuel Perea [1 2], Ester Devis [1], Ana Marcet [1], and Pablo Gomez [3]

[1] Departamento de Metodología, Universitat de València, Valencia, Spain

[2] BCBL. Basque Center on Cognition, Brain, and Language, Donostia, Spain

[3] Psychology Department, DePaul University, Chicago, USA

Running head: Go/no-go tasks and older adults

Address for correspondence:

Manuel Perea
Departamento de Metodología
Universitat de València
Av. Blasco Ibáñez, 21
46010-Valencia (Spain)
e-mail: mperea@uv.es

Authors' notes: This research has been partially supported by Grant PSI2014-53444-P from the Spanish Government. We thank Marc Brysbaert and an anonymous reviewer for very helpful comments on an earlier version of this paper.

Abstract

Recent research has shown that, in response time (RT) tasks, the go/no-go response procedure produces faster (and less noisy) RTs and fewer errors than the two-choice response procedure in children, although these differences are substantially smaller in college-aged adults. Here we examined whether the go/no-go procedure can be preferred to the two-choice procedure in RT experiments with older adults (i.e., another population with slower and more error-prone responding than college-aged individuals). To that end, we compared these response procedures in two experiments with older adults (M_{age} = 83 years): a visual word recognition task (lexical decision) and a perceptual task (numerosity discrimination). A group of young adults (M_{age} = 31 years) served as a control. In the lexical decision experiment, results showed a go/no-go advantage in the mean RTs and in the error rates for words; however, this was not accompanied by less noisy RT data. The magnitude of the word-frequency effect was similar in the two response procedures. The numerosity discrimination experiment did not reveal any clear differences across response procedures, except that the RTs were noisier in the go/no-go procedure. Therefore, we found no compelling reasons why the go/no-go procedure should be preferred over the two-choice procedure in RT experiments with older adults.

Key words: lexical decision; aging; task comparisons

It was nearly 150 years ago when Franciscus Donders started the study of mental chronometry. In his influential paper “On the speed of mental processes”, Donders (1868/1969) distinguished between choice and go/no-go tasks. In Donders’ original choice task, participants were presented with one of several syllables (ka, ke, ki, ko, ku) and were asked to pronounce (repeat) the syllable (i.e., “say ‘ka’ if you hear ‘ka’, say ‘ke’ if you hear ‘ke’…”). In the go/no-go task, participants were also presented with one of several syllables (ka, ke, ki, ko, ku), but they were asked only to respond to one of them (i.e., “say ‘ka’ if you hear ‘ka’, but do not respond if you hear another syllable”). Donders (1868/1969) found faster response times (RTs) in the go/no-go task than in the choice task and argued that this was due to a simpler “response organization” stage in the go/no-go task (see Gordon, 1983, for a similar reasoning). While the participants in the Donders experiment were asked to pronounce a syllable, the typical scenario in contemporary choice and go/no-go RT experiments involves pressing one or two keys. For instance, in the two-choice version of the lexical decision task (i.e., the most popular task in visual word recognition), participants are instructed to press a key for words and another key for nonwords, whereas in the go/no-go lexical decision task, participants are instructed to press a key for words and to refrain from responding to nonwords. (footnote 1)

Currently, the vast majority of RTs experiments with older adults employ two-choice rather than go/no-go response procedures (e.g., see Ratcliff, Thapar, & McKoon, 2007, for review). Given that RTs and error rates are typically higher in older adults than in college-aged adults, a theoretically and methodologically interesting question to ask is whether the go/no-go procedure, due to its simpler *response organization*, could be preferable to the two-choice procedure in RT experiments with older adults. Indeed, a parallel case has already been made for RT experiments with children (i.e., another population with slower and more error-prone responding than college-aged adults). In children, RTs in lexical decision are substantially shorter (and less noisy) with the go/no-go response procedure than with the two-choice response procedure; furthermore, this goes accompanied by lower rates of omissions and false alarms (e.g., see Gomez & Perea, 2012; Moret-Tatay & Perea, 2011; Perea, Soares, & Comesaña, 2013). For instance, Moret-Tatay and Perea concluded: "the go/no-go lexical decision task should be the preferred choice when conducting lexical decision experiments with young readers" (p. 131). As a result, the go/no-go response procedure is now becoming the standard method in RT experiments with children (e.g., Perea, Abu Mallouh, & Carreiras, 2013; Soares, Perea, & Comesaña, 2014; Wang, Castles, & Nickels, 2012).

The present experiments have both theoretical and methodological goals. The main theoretical goal is to examine the nature of the impact of the response procedure on standard RT tasks with older adults. Three outcomes are plausible: i) performance across different RT tasks is similarly affected by the introduction of the two-choice response procedure relative to the (allegedly simpler) go/no-go procedure, hence supporting the idea that the "response organization" stage plays an important role in RT experiments; ii) performance across different RT tasks is unaffected, thus suggesting that "response organization" is mostly automatic and task-independent; and iii) performance is affected in some RT tasks but not in others, hence suggesting that "response organization" interacts with the core processes of such tasks.

The methodological goal is to explore if the go/no-go procedure should be preferred over the two-choice procedure in RT experiments with older adults. To choose between the two procedures, we considered four criteria (see Perea, Rosa, & Gómez, 2002, for discussion): i) the speed of RTs (i.e., the faster the RTs, the less likely they can be affected by ancillary, task-specific processes); ii) the noise in the RT data (i.e., the less variability in the data, the higher the sensitivity of the task); iii) the number of omission errors and false alarms (i.e., the fewer the errors, the most likely that the effects of the critical factors are reflected in the RTs); and iv) sensitivity to theoretically relevant experimental manipulations—note that it has been claimed that, because of its simpler "task-specific decisional/motor demands" (Perea, Abu Mallouh, & Carreiras, 2014, p. 493), the go/no-go procedure can be more sensitive to small-sized effects than the two-choice procedure (see Bacon-Macé, Kirchner, Fabre-Thorpe, & Thorpe, 2007; Grice & Reed, 1992).

Only a few RT experiments have directly compared the two-choice procedure and the go/no-go procedure with older adults (Allen, Madden, Weber, & Groz, 1993; Allen, Weber, & Madden, 1994). In a lexical decision experiment with older adults (M_{age} = 70 years), Allen et al. (1993) found faster RTs in the go/no-go procedure than in the two-choice procedure—note that this go/no-go advantage was larger with older adults than with a group of young adults (120 vs. 38 ms, respectively). The effect under investigation (i.e., the effect of word-frequency: high- vs. low-frequency words) did not interact with response procedure. Despite the fact that RTs were substantially faster in the go/no-go than in the two-choice procedure, the across-participants RT variability (i.e., a marker of noise in the latency data) was similar in the two procedures (older adults: 136 vs. 154 ms, respectively). In addition, error rates on words were only slightly higher in the two-choice procedure than in the go/no-go procedure (1.2% for older adults and 2.6% for young adults). (footnote 2) Allen et al. (1993) interpreted these differences in terms of greater “response selection load” in the two-choice than in the go/no-go procedure. In a visual search experiment (e.g., “does the target contain a K?”), Allen et al. (1994) also found faster RTs in go/no-go procedure than in the two-choice procedure—again, the go/no-go advantage was larger with older than with young adults (169 vs. 109 ms, respectively). The effect size of the “target redundancy gain” (i.e., the effect under investigation in their study) was larger for older than for young adults, and it was also larger in the go/no-go procedure than in the two-choice procedure, but age and task procedure did not interact. The across-participant variability in the group of older adults was smaller in the go/no-go than in the two-choice procedure (95 vs. 144 ms, respectively). Error rates were also lower in the go/no-go procedure than in the two-choice procedure (3.0 vs. 7.3% in the groups of older and young adults, respectively, respectively). Taken together, the experiments of Allen et al. (1993, 1994) suggest that the go/no-go procedure produces an advantage over the two-choice procedure in the mean RTs and error rates. However, the evidence concerning which response procedure is more sensitive to the experimental manipulation is unclear: while Allen et al. (1993) found a similar word-frequency effect in the two procedures, Allen et al. (1994) found a greater target redundancy gain in the go/no-go procedure than in the two-choice procedure (see also Grice & Reed, 1992, for a greater target redundancy gain in the go/no-go procedure than in the two-choice procedure with college-aged adults).

In addition, a number of RT experiments have compared the go/no-go and two-choice procedures in college-aged adults. In the lexical decision task, the data have consistently revealed faster RTs and fewer errors to word stimuli in the go/no-go than in the two-choice procedure; however, the evidence concerning the variability in the RT data and the false alarm rate is inconclusive (e.g., see Gordon, 1983; Perea et al., 2002). To compare in detail the intricacies of the go/no-go and two-choice procedures with college-aged students, Gomez, Ratcliff, and Perea (2007) conducted a series of experiments using a variety of tasks (lexical decision, recognition memory, and numerosity discrimination). Furthermore, they examined if the differences across response procedures involved changes in core decisional processes or rather changes in ancillary processes. To that end, they employed a widely used mathematical model of RT tasks, namely, Ratcliff's (1978) diffusion model. On the basis of the accuracy data and the RT distributions for correct/error responses in each of condition, the diffusion model provides parameter values of the underlying cognitive processes in RT tasks: i) core decisional processes (i.e., the quality of information extraction entering the decision process: *drift rates* in the diffusion model); and ii) ancillary processes (i.e., time of encoding and response execution [T_{er} in the model] and decision criteria [i.e., a or z in the model]; see Ratcliff, Gomez, & McKoon, 2004, for extensive discussion). (footnote 3) Importantly, across the various tasks with the go/no-go and two-choice response procedure, Gomez et al. (2007) found that the differences across task procedures occurred in the parameters related to ancillary processes (i.e., decision criteria, T_{er}) rather than in the parameter related to core processes (i.e., *drift rates*) and concluded: “the go/no-go procedure has rather limited benefits compared with the two-choice procedure” (p. 411). Nonetheless, the story may be more complex in experiments with other populations (e.g., children or older adults), as college-aged adults presumably enjoy optimal quality of information entering the decision process (i.e., *drift rates*). There is evidence that shows that *drift rates* in children are substantially smaller than those in college-aged adults (Ratcliff, Love, Thompson, & Opfer, 2012). Gomez and Perea (2012) replicated this pattern (i.e., lower drift rates for developing readers than for college-aged adults). Importantly, Gomez and Perea found that, in children, response procedure (go/no-go vs. two-choice) affected core processes in two RT tasks (lexical decision and numerosity discrimination): *drift rates* were higher in the go/no-go than in the two-choice procedure. However, with older adults, the evidence concerning the modulation of *drift rates* as a function of age is not conclusive and seems to be domain-dependent. On the one hand, Ratcliff, Thapar, and McKoon (2007) reported that the *drift rates* remained intact (i.e., no decline) with age in a number of two-choice-tasks including lexical decision (i.e., *drift rates* were approximately similar for 75- to 90-year-olds as for college-aged students). On the other hand, Spaniol, Madden, and Voss (2006) found higher values in the *drift rate* parameter for younger than for older adults in two recognition memory experiments.

In the current series of experiments, we examined whether the go/no-go procedure is preferable to the two-choice procedure in RT experiments with older adults (M_{age} = 83 years). A group of young adults served as a control (M_{age} = 31 years). Note that, unlike other studies in which the comparison group is a college-aged sample that participated as a requirement in an undergraduate class, we used a post-college sample that participated as volunteers, just like the older adults. To reach wide-ranging conclusions, we compared the go/no-go vs. two-choice procedures in two very different tasks (see Gomez et al., 2007, for a similar approach). In Experiment 1, we employed the most popular task in visual word recognition: lexical decision ("is the item a word?"). To examine if response procedure affects core processes during lexical access in older adults, we also manipulated an index of difficulty of lexical access: word-frequency (high-frequency words vs. low-frequency words). In Experiment 2, we employed a perceptual task: a numerosity discrimination task ("are there more than 50 dots?"; Espinoza-Varas & Watson, 1999; see also Gomez et al., 2007; Ratcliff, Van Zandt, & McKoon, 1999). To examine if response procedure affects the core processes in the numerosity discrimination task with older adults, we manipulated an index of task difficulty: easy (27-35, 65-73 dots) vs. difficult (36-44, 56-64 dots). As in previous research, task procedure (go/no-go vs. two-choice) was manipulated within-subjects (e.g., see Allen et al., 1993; Gomez et al., 2007; Perea et al., 2002).

Experiment 1 (lexical decision task)

The predictions in the current lexical decision experiment are straightforward: if the pattern of data with older adults is similar to that obtained with children (i.e., faster RTs, less noisy RTs, fewer omission errors, and fewer false alarms in the go/no-go than in the two-choice procedure), the go/no-go procedure should be the preferred method in lexical decision experiments with older adults—at least if the go/no-go procedure is as sensitive to the effect under scrutiny (i.e., word-frequency) as the two-choice procedure. Alternatively, if the pattern of data with older adults is similar to that obtained with college-aged adults (i.e., faster RTs and fewer omission errors, but no effect in the variability of the RTs or in the rate of false alarms), the two-choice procedure should continue to be the preferred method with older adults—note that, *ceteris paribus*, the two-choice procedure provides more data points than the go/no-go procedure and, thereby it may be more constraining for theoretical models (see Gomez et al., 2007).

Method

Participants. 16 older adults (11 female; M_{age} = 82.7 years; SD = 5.3; range: 71-93) and 16 young adults (10 female; M_{age} = 31.3 years, SD = 3.4, range: 28-37) took part voluntarily in the experiment and gave written informed consent. All participants had normal (or corrected-to-normal) vision, were native speakers of Spanish, and reported reading on a daily basis. The young adults were recent graduates from the University of Valencia. The older adults had been recruited in two retirement homes in Valencia, Spain. None of the older adults had any cognitive impairment, as deduced from the results of the Spanish adaptation of the Mini-Mental-State-Examination (Folstein, Folstein, & McHugh, 1975; Lobo et al., 1999) (M = 33.25; the maximum value is 35 in the Spanish adaptation) and from the assessment of two psychologists at the retirement homes. Participants were also excluded if they had any medical, psychiatric, or neurological problems, including mood disorders or anxiety. To discard any potential participant in a depressive mood, we employed the Geriatric Depression Scale (Yesavage et al., 1983; Spanish adaption by Martínez de la Iglesia et al., 2002) (M = 4.3). None of the participants had motor skills disorders in their arms or hands. One of the participants in the "older adult" group was replaced because did not follow the instructions (error rates were above 40%).

Materials. We selected 120 Spanish words of five letters from the B-Pal database (Davis & Perea, 2005): 60 high-frequency words (M = 147 occurrences per million) and 60 low-frequency words (M = 10 occurrences per million). We also employed 120 orthographically legal pseudowords. This set of words/pseudowords was the same as in experiment with developing readers conducted by Moret-Tatay and Perea (2011). Two lists of stimuli were created: 60 words (30 low-frequency and 30 high-frequency words) and 60 pseudowords were randomly assigned to List 1. The remaining sixty words and sixty pseudowords were assigned to List 2. Half of the participants were assigned List 1 in the first block, and List 2 in the second block; the other half was assigned the lists in the reverse order. Each block was preceded by 16 practice trials to familiarize participants with the task.

Procedure. The experiment took place in a silent room with groups of up to four participants. DMDX software (Forster & Forster, 2003) was employed to present the stimuli and register the participants' responses. The sequence of a given trial was the following: 1) a fixation point (+) was presented for 500 ms in the center of the screen; 2) a lowercase 14-pt Times Roman item was presented in the center of the screen until the participant's response—or until 2500 ms had elapsed. In the go/no-go block, participants were instructed to press the "sí" (yes) button when the letter string was a Spanish word and refrain from responding if the letter string was not a word. In the two-choice block, participants were instructed to press the "sí" (yes) button when the letter string was a Spanish word, and to press the "no" button when the letter string was not a word. Both speed and accuracy were stressed in the instructions. Responses to words were made with the participant's dominant hand. Stimulus presentation was randomized for each participant. The session lasted approximately 12-16 min.

Results and Discussion

Incorrect responses and RTs shorter than 250 or longer than 2000 ms (less than 0.7 and 0.1% for word stimuli in the older and young adult groups, respectively) were excluded from the RT analyses. The mean and standard deviation RTs for correct responses and the error rates for each condition are displayed in Table 1. For the word data, analyses of variance (ANOVAs) based on the participants' mean RTs, standard deviation RTs, and percent error were conducted on the basis of a 2 (response procedure: go/no-go, two-choice) x 2 (word-frequency: high, low) design. (footnote 4) For the nonword data, ANOVAs based on the participants' percent error were conducted on the basis of a single factor with two levels (response procedure: go/no-go, two-choice) design.

Insert_Table_1_around_here

Word data. Lexical decision times were, on average, 331 ms faster in the group of young adults than in the group of older adults (552 vs 883 ms, respectively), $F(1,30) = 47.49$, $\eta^2 = .61$, $p < .001$. In addition, lexical decision times were, on average, 55 ms faster on high-frequency words than on low-frequency words, $F(1,30) = 75.0$, $\eta^2 = .71$, $p < .001$. More importantly, lexical decision times were, on average, 80 ms faster in the go/no-go procedure than in the two-choice procedure, $F(1,30) = 17.43$, $\eta^2 = .37$, $p < .001$. The effect of word-frequency was comparable in the two procedures, as deduced from the lack of interaction between these two factors, $F < 1$. The interaction between Age and Procedure was significant, $F(1,39) = 4.55$, $\eta^2 = .12$, $p = .04$. This interaction revealed that the go/no-go advantage was larger with older adults than with young adults (121 vs 39 ms; older adults: $F(1,15) = 12.34$, $\eta^2 = .45$, $p = .003$; young adults: $F(1,15) = 8.41$, $\eta^2 = .36$, $p = .011$).

The ANOVA on the standard deviation RTs showed that there was more variability in the data from the older adults than in the data from the young adults, $F(1,30) = 33.31$, $\eta^2 =.53$, $p < .001$. In addition, there was more variability in the data from low-frequency words than in the data from high-frequency words, $F(1,30) = 16.14$, $\eta^2 =.35$, $p < .001$. The other effects/interactions did not approach significance (all *p*s > .25).

The ANOVA on the error data for words revealed that older adults committed more errors than the young adults, $F(1,30) = 11.53$, $\eta^2 = .28$, $p = .002$. Participants committed more errors on low-frequency words than on high-frequency words, $F(1,30) = 8.01$, $\eta^2 = .21$, $p = .008$, and participants made committed errors in the two-choice than in the go/no-go procedure, $F(1,30) = 11.13$, $\eta^2 = .27$, $p = .002$. The three-way interaction between Age, Procedure and Word-frequency was significant, $F(1,30) = 6.45$, $\eta^2 = .17$, $p = .019$. This reflected that the effect of word-frequency was greater in the two-choice procedure than in the go/no-go procedure—note that this was essentially due to a floor effect in the go/no-procedure (see Moret-Tatay & Perea, 2011, for a similar interaction with developing readers).

Pseudoword data. The ANOVA on the error rates on pseudowords (i.e., false alarm rates) showed that older adults made more errors than the young adults, $F(1,30) = 10.39$, $\eta^2 = .26$, $p = .003$. Neither the effect of task procedure not the interaction between the two factors approached significant (both Fs < 1).

Overall, the current lexical decision experiment showed that older adults had longer RTs, noisier RT data, and more errors than young adults. Leaving aside these differences, the go/no-go vs. two-choice procedures produced a similar pattern to that reported in previous experiments with college-aged adults (e.g., see Gomez et al., 2007; Perea et al., 2002): i) RTs were faster in the go/no-go procedure than in the two-choice procedure—note that the go/no-go advantage in the mean RTs was larger with older adults than with young adults (see Allen et al., 1993, for a similar interaction); ii) there were fewer errors to word stimuli in the go/no-go than in the two-choice procedure; iii) there were no differences across task procedures in the error rates to pseudowords (i.e., false alarms); iv) there were no differences across task procedures in the variability of the

RT data; and v) the magnitude of the word-frequency effect was similar in the two task procedures. Taken together, the differences across response procedures can be readily explained in terms of differences in ancillary, task-specific processes in a diffusion model (e.g., time of encoding and response execution; decision criteria) rather than in core decisional processes (*drift rates*; see Gomez et al., 2007). We defer a more in-depth analysis of this issue, including the analysis of the RT distributions, until the General Discussion.

The question now is whether the differences between the go/no-go vs. two-choice procedures also arise when using a non-verbal, perceptual task: the numerosity discrimination task (“are there more than 50 dots?”). This is the goal of Experiment 2. We also manipulated the difficulty of the task (“easy” trials [27-35, 65-73 dots], “difficult” trials [36-44, 56-64 dots]). If the go/no-go advantage were due to a simpler “response organization” that does not interact with the specific RT task, one would expect faster RTs in the go/no-go version of the numerosity discrimination task than in the two-choice version of the task. Nonetheless, in a numerosity discrimination experiment with college-aged adults, Gomez et al. (2007) did not find any differences due to response procedure (go/no-go vs. two-choice) in the mean RTs or in the RT distributions—the only difference was that the go/no-go procedure produced fewer errors than the two-choice procedure, particularly for “go” responses.

Experiment 2 (numerosity discrimination task)

Method

Participants. The participants were the same as in Experiment 1. Half of them had participated in Experiment 1 the previous month and the other half took part in Experiment 1 one month later.

Materials. For the condition with a "low" number of dots (i.e., less than 50 dots in a 10x10 grid), the number of dots was generated by randomly sampling from a uniform distribution with end points 27 and 44—there were 72 "low" trials. For the condition with a "high" number of dots (i.e., more than 50 dots in a 10x10 grid), the number of dots was selected by randomly sampling from a uniform distribution with end points 56 and 73—there were 72 "high" trials. For comparison purposes with Experiment 1, we collapsed the data into two groups (interval size = 9): "easy" trials (27-35 and 65-73 dots) and "difficult" trials (36-44 and 56-64 dots).

Procedure. Participants were tested, in groups of up to four individuals, in a quiet room. We employed DMDX (Forster & Forster, 2003) to present the stimuli and register the participants' responses. This is the sequence of a given trial: 1) there was a fixation point ("+") at the center of the computer screen for 500 ms; 2) a matrix of dots was presented in a 10x10 grid until the participant responded or until 2000 ms had passed. In the go/no-go block, participants were instructed to press the button labeled as "+" when the number of dots was high (more than 50) and refrain from responding when the number of dots was low (less than 50). In the two-choice block, participants were instructed to press a key labeled as "+"when the number of dots was high (more than 50) and to press a key labeled as "-" when the number of dots was low (less than 50). As in previous experiments with this task (e.g., Gomez et al., 2007), participants received accuracy feedback after each trial. The “+” responses were made with the participant's dominant hand. All participants received the two task procedures in same experimental session: half of the participants performed the go/no-go block first, while the other half performed the two-choice block first. The entire session took around 14-18 min.

Results and Discussion

Incorrect responses and RTs shorter than 250 ms or longer than 2000 ms were excluded from the latency analyses (less than 1.2% for the older adults, less than 0.1% for the younger adults). The mean and standard deviation RTs for correct responses and the error rates are displayed in Table 2. ANOVAs based on the participants’ response latencies (both mean RTs and standard deviation RTs) for the “high number of dots” responses were conducted on the basis of a 2 (response procedure: go/no-go, two-choice) x 2 (difficulty: easy, difficult) design. The statistical analyses on the error data were similar to the RT analyses, except that “number of dots” (low, high) was also included as a factor in the design.

Insert_Table_2_around_here

Latency data (high number of dots). The ANOVA on the mean RTs showed that young adults were, on average, 243 ms faster than the older adults, $F(1,30) = 22.60$, $\eta^2 = .43$, $p < .001$. In addition, response times were, on average, 70 ms faster in the easy trials than in the difficult trials, $F(1,30) = 107.93$, $\eta^2 = .78$, $p < .001$. None of the effects/interactions approached significance, all *p*s > .14.

The ANOVA on the standard deviation RTs revealed that there was more variability in the data from the older adults than in the data from the young adults, $F(1,30) = 16.40$, $\eta^2 = .35$, $p < .001$. In addition, there was more variability in the RT data from difficult trials than in the RT data from easy trials, $F(1,30) = 57.01$, $\eta^2 = .66$, $p < .001$. Furthermore, there was more variability in the go/no-go procedure than in the two-choice procedure, $F(1,30) = 4.32$, $\eta^2 = .13$, $p = .046$. None of the other effects/interactions approached significant, all *p*s > .29.

Error data. The ANOVA on the error data revealed that older adults made more errors than young adults, $F(1,30) = 7.27$, $\eta^2 = .20$, $p = .011$. There were no signs of a difference between the number of errors in the go/no-go and two-choice procedures, $F < 1$. In addition, participants committed more errors for the difficult trials than for the easy trials, $F(1,30) = 98.05$, $\eta^2 = .77$, $p < .001$. The effect of difficulty was greater for the older adults than for the young adults (10.4% vs. 4.5%, respectively), as deduced from the interaction between Difficulty and Age, $F(1,30) = 15.19$, $\eta^2 = .34$, $p = .001$. None of the other interactions was significant (all *p*s > .10).

To summarize, results from Experiment 2 showed that, in a numerosity discrimination task, mean RTs, standard deviation RTs, and error rates were higher in older than in young adults. More importantly for our goals, the numerosity discrimination task did not reveal any signs of a difference in the mean RTs across response procedures; furthermore, the two procedures were equally sensitive to the effect of difficulty. Note, however, that for older adults, accuracy was slightly higher in the go/no-go procedure for all conditions. Finally, the variability in the RT data was higher (not smaller as expected) in the go/no-go procedure than in the two-choice procedure.

General Discussion

The present experiments had (inter-related) methodological and theoretical goals. In terms of the main methodological aim, we examined if the go/no-go procedure should be the preferred method of data collection for RT experiments with older adults. The go/no-go response procedure is becoming the preferred method in RTs experiments with children because it produces faster RTs, less noisy data, and fewer error responses than the two-choice procedure (e.g., Perea et al., 2013; Soares et al., 2014; Wang et al., 2012). Would the same principles apply to older adults (i.e., another population that yields longer RTs and more errors than college-aged adults)? We conducted two RT experiments with older adults: a word recognition task (lexical decision task) and a perceptual task (numerosity judgment task). In the lexical decision task (Experiment 1), responses to words were faster and more accurate in the go/no-go procedure than in the two-choice procedure—this effect was greater for older adults than for young adults, thus replicating the pattern reported by Allen et al. (1993). Importantly, the effect under investigation (i.e., the word-frequency effect) was similar in magnitude with the two response procedures. Furthermore, neither the variability in the RT data nor the false error rates (i.e., “word” responses to pseudowords) was affected by response procedure. In the numerosity discrimination task (Experiment 2), we found no differences in the mean RTs or error rates across response procedure. The effect of difficulty (number of dots close to 50 vs. distant from 50) was of similar magnitude in the go/no-go and two-choice procedures—this effect was greater for older adults than for young adults in the error data. Furthermore, in the numerosity discrimination experiment, the go/no-go procedure yielded noisier RT data than the two-choice procedure. Taken together, results did not support the notion that the go/no-go response procedure should be preferred to the two-choice response procedure in older adults.

The main theoretical aim was to determine if, in older adults, the (alleged) increased demands due to "response organization" in the two-choice response procedure would affect the core processes in a lexical decision task and in a (perceptual) numerosity discrimination task. Unfortunately, as is often the case in psychology experiments, the answer to this question is nuanced and tentative. While there is a main effect of response procedure on lexical decision performance, there is no sign of an effect of response procedure on the numerosity discrimination task. The present results lead us to revisit the Gomez et al. (2007) article that featured similar experiments as those reported here, but with college-aged adults. A feature of the data that was not discussed by Gomez et al. (2007) was that the numerosity discrimination experiments showed effects of go/no-go vs. two-choice procedures that were dramatically smaller than the effects obtained in their lexical decision experiments. Indeed, the only difference between the performance by older adults in our numerosity experiment and in the Gomez et al. (2007) experiment is that they found greater accuracy (for "go" but not for "no-go" responses) in the go/no-go procedure than in the two-choice procedure. In the current experiment, there was an overall improvement in accuracy, but it was not statistically significant.

Notably, the pattern of data in the lexical decision experiment with older adults was similar to that obtained in experiments with college-aged adults (e.g., Gomez et al., 2007; Perea et al., 2002): there was an advantage of the go/no-go procedure in the mean RTs and in the number of errors to words (i.e., “nonword” responses to word stimuli). However, the magnitude of the word-frequency effect was approximately similar in the two procedures, and there were no differences in the variability of the RTs across procedures. To explore in further detail the similarities/differences between the two response procedures, we examined the RT distributions (e.g., Ratcliff, 1978; see also Gomez et al., 2007, for similar RT distributional analyses). The group RT distributions in the lexical decision task are displayed in Figure 1. Each column of dots represents the five RT quantiles (.1, .3, .5, .7, and .9) per condition, whereas the abscissas represent accuracy. Unsurprisingly, the asymmetry is larger for the low-frequency words than for the high-frequency words in the two procedures: this can be easily modeled as a change in *drift rates* in the diffusion model (see Gomez et al., 2007, for discussion). (Note that changes in *drift rate* across conditions necessarily imply that the RT distribution of the slower condition is more asymmetric than the RT distribution of the faster condition.) But the relevant point here is that the shape of the RT distributions is similar in the two procedures (i.e., there is just a shift in the RT distributions). This is exactly the same pattern of RT distributions reported by Gomez et al. (2007) with college-aged students, the only difference being that the go/no-go advantage in RTs is greater with older adults than with young adults (see also Allen et al., 1993, for a similar interaction). For simplicity's purposes, we did not conduct any fits on the diffusion model in the present experiments. What we should note, however, is that, pending some formal analyses, the geometry of the model allows us to make some basis predictions on the basis of the RT distributions and the accuracy data.

Insert_Figure_1_around_here

Thus, as in the Gomez et al. (2007) lexical decision experiments with college-aged adults, the differences between response procedures (go/no-go vs. two-choice) with older adults can be accounted for in terms of non-decisional time (i.e., time of encoding and response execution) and changes in decision criteria rather than in the evidence accumulation process (i.e., the quality of extraction of information: *drift rates*) in a diffusion model. This reasoning is consistent with the claims that, in lexical decision, the quality of extraction of information (i.e., *drift rates*) is approximately similar in college-aged students and in older adults (see Ratcliff et al., 2007). Specifically, Ratcliff et al. (2007) accounted for the differences in RTs between young and older adults in lexical decision in terms of differences in the time of encoding and response execution (T_{er}) and in the decision criteria (i.e., older adults are more conservative in their decision thresholds than the young participants)—note that the scenario can be different in RT experiments with children, as the quality of extraction of information in children is lower than in adults (Ratcliff et al., 2011; see also Gomez & Perea, 2012).

Insert_Figure_2_around_here

Revisiting the diffusion model fits in the Gomez et al. (2007) paper reveals that in the lexical decision task, the effect of response time on the parameter termed T_{er} (i.e., time of encoding and response execution) was three times larger in the lexical decision task than in the numerosity discrimination task. This difference was overlooked by Gomez et al. (2007), and given that there was an effect of response procedure in the two experiments (even if it was very different in size), it was attributed to the time of encoding and response execution. We believe that this interpretation should be reviewed: recent work suggests lexical factors (e.g., word-frequency) influence the T_{er} parameter (see Gomez & Perea, 2014). As indicated earlier, this parameter is associated to shifts in the RT distributions. To that end, we examined the RT distributions for the numerosity discrimination task. As can be seen in Figure 2, the RT distributions were similar in the two response procedures. That is, in the present data and in the Gomez et al. (2007) data, we found a large shift in the RT distributions across response procedure in the lexical decision task, but not in the numerosity discrimination task. Therefore, it appears that response procedure is influencing the time of encoding and response execution (T_{er}) in the lexical (more abstract) task to a larger degree than in the perceptual, non-verbal task—note that the T_{er} parameter in the lexical decision task can be affected not only by early encoding processes but also, to a smaller degree, by lexical processes like word-frequency (Gomez & Perea, 2014), contrary to Ratcliff et al.'s (1994) minimal assumption that only drift rate would relate to lexical processes. Indeed, results in the numerosity discrimination experiment failed to show an advantage of the go/no-go over the two-choice procedure in the mean RTs. This is entirely consistent with the data from

Gomez et al. (2007) with college-aged adults. The only (nonsignificant) difference is that, for the older adults, accuracy was slightly higher in the go/no-go procedure in all conditions—note that this difference was significant in the Gomez et al. (2007) experiment with college-aged adults but only for "go" responses. In a diffusion model, this pattern can be readily accounted for in terms of changes in the decision criteria (parameters *a* and *z*) rather than by changes in the quality of information (*drift rates*) or in the time of encoding and response execution (T_{er}) (see Gomez et al., 2007, for fits of the model). That is, age differences in cognitive tasks do not appear to be due to changes in the demands imposed by response organization.

In sum, the present experiments demonstrated that the go/no-go procedure only has "limited benefits" with respect to the (standard) two-choice procedure in RT experiments with older adults (i.e., faster responding and fewer errors to words in lexical decision). Given that the two-choice procedure provides more data points than the go/no-go procedure (i.e., RT data for the two types of responses), the two-choice procedure may be more constraining for theoretical models than the go/no-go procedure (see Gomez et al., 2007, for discussion). Therefore, at a methodological level, we found no compelling reasons why the go/no-go procedure should be preferred over the two-choice procedure in RT experiments with older adults. Finally, given that task (go/no-go vs. two-choice) affected performance in a lexical decision, but not in a numerosity discrimination task, the effect of "response organization" seems to depend on which core process is being performed (lexical vs. concrete). Further research is necessary to examine in detail the time course of processing in RT tasks using go/no-go and two-choice procedures in young and older adults (e.g., by measuring the ERP waves).

References

Allen, P. A., Madden, D. J., Weber, T. A., & Groth, K. E. (1993). Influence of age and processing stage on visual word recognition. *Psychology and Aging, 8*, 274-282. DOI: 10.1037/0882-7974.8.2.274

Allen, P. A., Weber, T. A., & Madden, D. J. (1994). Adult age differences in attention: filtering or selection? *Journal of Gerontology, 49*, P213-P222. DOI: 10.1093/geronj/49.5.p213

Bacon-Macé, N., Kirchner, H., Fabre-Thorpe, M., & Thorpe, S. J. (2007). Effects of task requirements on rapid natural scene processing: From common sensory encoding to distinct decisional mechanisms. *Journal of Experimental Psychology Human Perception and Performance, 33*, 1013–1026. DOI: 10.1037/0096-1523.33.5.1013

Davis, C. J., & Perea, M. (2005). BuscaPalabras: A program for deriving orthographic and phonological neighborhood statistics and other psycholinguistic indices in Spanish. *Behavior Research Methods, 37*, 665-671. DOI: 10.3758/BF03192738

Donders, F. C. (1969). On the speed of mental processes. *Acta Psychologica, 30*, 412-431. DOI 10.1016/0001-6918(69)90065-1 (Original work published in 1868)

Espinoza-Varas, B., & Watson, C. (1994). Effects of decision criterion on response latencies of binary decisions. *Perception and Psychophysics, 55*, 190-203. DOI: 10.3758/BF03211666

Folstein, M., Folstein, S. E., & McHugh, P. R. (1975). “Mini-Mental State”: A practical method for grading the cognitive state of patients for the clinician. *Journal of Psychiatric Research, 12*, 189-198. DOI: 10.1016/0022-3956(75)90026-6

Forster, K. I., & Forster, J. C. (2003). DMDX: a Windows display program with millisecond accuracy. *Behavior Research Methods, Instruments, & Computers, 35*, 116-124. DOI: 10.3758/BF03195503.

Gomez, P., & Perea, M. (2012, November). *Response method (go/no-go vs. two-choice) interferes with core processes in children*. Paper presented at the 53rd Annual Meeting of the Psychonomic Society, Minneapolis.

Gomez, P., & Perea, M. (2014). Decomposing encoding and decisional components in visual-word recognition: A diffusion model analysis. *Quarterly Journal of Experimental Psychology, 67*, 2455-2466. DOI: 10.1080/17470218.2014.937447

Gomez, P., Perea, M., & Ratcliff, R. (2013). A diffusion model account of masked vs. unmasked priming: Are they qualitatively different? *Journal of Experimental Psychology: Human Perception and Performance, 39*, 1731-1740. DOI: 10.1037/a0032333

Gomez, P., Ratcliff, R., & Perea, M. (2007). A model of the go/no-go task. *Journal of Experimental Psychology: General, 136*, 389-413. DOI: 10.1037/0096-3445.136.3.389

Gordon, B. (1983). Lexical access and lexical decision: Mechanisms of frequency sensitivity. *Journal of Verbal Learning and Verbal Behavior, 22*, 24-44. DOI: 10.1016/S0022-5371(83)80004-8

Grice, G. R., & Reed, J. M. (1992). What makes targets redundant? *Perception & Psychophysics, 51*, 437-442. DOI: 10.3758/ BF03211639

Lobo, A., Saza, P., Marcos, G., Díaz, J. L., De la Cámara, C., Ventura, T., et al. (1999). Revalidación y normalización del Mini-Examen Cognoscitivo (primera versión en castellano del Mini-Mental Status Examination) en la población general geriátrica. *Medicina Clínica, 112*, 767-74.

Martínez-de la Iglesia, J., Onis-Vilches, M. C., Dueñez-Herrero, R., Aguado-Taberné, C., Albert-Colomer, C., & Luque-Luque, R. (2002). Versión española del cuestionario de Yesavage abreviado para el cribado de depresión en mayores de 65 años. Adaptación y validación. *Medifam 12*, 620-630. DOI: 10.4321/S1131-57682002001000003

Moret-Tatay, C., & Perea, M. (2011). Is the go/no-go lexical decision task preferable to the yes/no task with developing readers? *Journal of Experimental Child Psychology, 110*, 125-132. DOI: 10.1016/j.jecp.2011.04.005

Perea, M., Abu Mallouh, R., & Carreiras, M. (2013). Early access to abstract representations in developing readers: Evidence from masked priming. *Developmental Science, 16*, 564-573. DOI: 10.1111/desc.12052

Perea, M., Abu Mallouh, & Carreiras, M. (2014). Are root letters compulsory for lexical access in Semitic languages? The case of masked form-priming in Arabic. *Cognition, 132*, 491-500. DOI: 10.1016/j.cognition.2014.05.008

Perea, M., Gomez, P., & Fraga, I. (2010). Masked nonword repetition effects in yes/no and go/no-go lexical decision: A test of the Evidence Accumulation and Deadline accounts. *Psychonomic Bulletin and Review, 17*, 369-374. DOI: 10.3758/pbr.17.3.369

Perea, M., Rosa, E., & Gómez, C. (2002). Is the go/no-go lexical decision task an alternative to the yes/no lexical decision task? *Memory and Cognition, 30*, 34–45. DOI: 10.3758/BF03195263

Perea, M., Rosa, E., & Gómez, C. (2005). The frequency effect for pseudowords in the lexical decision task. *Perception and Psychophysics, 67*, 301-314. DOI: 10.3758/bf03206493

Perea, M., Soares, A. P., & Comesaña, M. (2013). Contextual diversity is a main determinant of word-identification times in young readers. *Journal of Experimental Child Psychology, 116*, 37-44. DOI: 10.1016/j.jecp.2012.10.014

Ratcliff, R. (1978). A theory of memory retrieval. *Psychological Review, 85*, 59–108. DOI: 10.1037/0033-295X.85.2.59

Ratcliff, R., Gomez, P., & McKoon, G. (2004). A diffusion model account of the lexical decision task. *Psychological Review, 111*, 159–182. DOI: 10.1037/0033-295X.111.1.159

Ratcliff, R. (2008). Modeling aging effects on two-choice tasks: Response signal and response time data. *Psychology and Aging, 23*, 900-916. DOI: 10.1037/a0013930

Ratcliff, R., Thapar, A., & McKoon, G. (2007). Application of the diffusion model to two-choice tasks for adults 75-90 years old. *Psychology and Aging, 22*, 56-66. DOI: 10.1037/0882-7974.22.1.56

Ratcliff, R., Love, J., Thompson, C. A., & Opfer, J. (2012). Children are not like older adults: A diffusion model analysis of developmental changes in speeded responses. *Child Development, 83,* 367-381. DOI: 10.1111/j.1467-8624.2011.01683.x

Soares, A.P., Perea, M., & Comesaña, M. (2014). Tracking the emergence of the consonant bias in visual-word recognition: Evidence with developing readers. *PLoS ONE, 9*(2), e88580. DOI: 10.1371/journal.pone.0088580

Spaniol, J., Madden, D. J., & Voss, A. (2006). A diffusion model analysis of adult age differences in episodic and semantic long-term memory retrieval. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, *32*, 101-117. DOI: 10.1037/0278-7393.32.1.101

Vilalta, J., Llinás, S., López-Pousas, A., Amiel, J., & Vidal, C. (1990). CAMDEX. Validación de la adaptación española. *Neurología, 5*, 117-120.

Yesavage, J. A., Brink, T. L., Rose, T. L., Lum, O., Huang, V., Adey, M., & Leirer, V. O. (1983). Development and validation of a geriatric depression screening scale: A preliminary report. *Journal of Psychiatric Research, 17*, 37-49. DOI: 10.1016/0022-3956(82)90033-4

Wang, H.-C., Castles, A., & Nickels, L. (2012). Word regularity affects orthographic learning. *Quarterly Journal of Experimental Psychology, 65*, 856-864. DOI: 10.1080/17470218.2012.672996

Table 1. Mean RTs (in ms), percentage of errors (in parentheses), and mean standard deviation across participants in the RT data (in ms, in italics) for the stimuli in Experiment 1 (lexical decision task)

	Word Frequency		
	Low	High	Pseudowords
Younger Adults			
go/no-go procedure	556 (0.0) *119*	508 (0.0) *74*	---- (0.5) ---
two-choice procedure	591 (2.3) *117*	552 (0.7) *89*	617 (1.7) *111*
Older adults			
go/no-go procedure	851 (1.0) *195*	793 (0.4) *181*	---- (15.3) ---
two-choice procedure	978 (5.8) *170*	908 (1.7) *204*	1148 (15.0) *234*

Table 2. Mean RTs (in ms), percentage of errors (in parentheses and mean standard deviation across participants in the RT data (in ms, in italics) for the stimuli in Experiment 2 (numerosity discrimination task)

	"Low" number of dots		"High" number of dots	
	Easy	Difficult	Easy	Difficult
Young Adults				
go/no-go procedure	--- (3.9) ---	--- (9.4) ---	490 (0.3) *98*	550 (2.1) *143*
two-choice procedure	554 (2.4) *128*	571 (7.6) 111	493 (1.2) *86*	548 (6.6) *135*
Older adults				
go/no-go procedure	--- (1.9) ---	--- (14.6) ---	702 (4.0) *156*	748 (12.2) *222*
two-choice procedure	732 (3.8) *136*	817 (17.0) *178*	696 (5.2) *134*	761 (12.7) *193*

Footnotes

1. In some go/no-go lexical decision experiments, participants are asked to press a key for nonwords and refrain to respond to words (e.g., Perea, Gomez, & Fraga, 2010; Perea, Rosa & Gómez, 2005).
2. We thank Philip Allen for sharing these data with us.
3. For instance, when there are changes in *drift rate* across conditions (e.g., high-frequency words vs. low-frequency words in lexical decision), the slower condition (i.e., low-frequency words) shows a larger positive asymmetry and more errors than the faster condition (Gomez et al., 2007); in contrast, when there are only changes in the time of encoding and response execution across conditions (e.g., masked repetition priming: identity vs. unrelated conditions; word rotation: 0º vs. 45º), there is only a shift in the RT distributions (see Gomez, Perea, & Ratcliff, 2012; Gomez & Perea, 2014).
4. Neither list (list 1, list 2) nor order (go/no-go → two-choice, two choice → go/no-go) had any impact on any of the dependent variables, and they were not included in the reported ANOVAs.

Figure Captions

Figure 1. The two panels show the Accuracy-Quantile plots for older adults (top panel) and young adults (bottom panel) in the lexical decision experiment. The data from the go/no-go procedure tasks are in black and the data from the two-choice procedure are in red. The x-axis represents the accuracy (probability of correct responses) while the y-axis represents the latency. The columns of points are the latencies at the .1, .3, .5, .7, and .9 quantiles (in ms). The responses to the different types of items are represented as follows: H=high-frequency words, L=low-frequency words, N=nonwords. Because there are no latencies for nonwords in the go/no-go procedure, the accuracy is represented by the dotted line (at .847).

Figure 2. The two panels show the Accuracy-Quantile plots for older adults (top panel) and young adults (bottom panel) in the numerosity discrimination experiment. The data from the go/no-go procedure are in black and the data from the two-choice procedure are in red. The x-axis represents the accuracy (probability of correct responses) while the y-axis represents the latency. The columns of points are the latencies at the .1, .3, .5, .7, and .9 quantiles (in ms). The responses to the different types of items are represented as follows: E=Easy trials with many dots, D=Difficult trials with many dots, e=easy trials with few dots, d=difficult trials with few dots). Because there are no latencies for "few dots" in the go/no-go procedure, the accuracies are represented by the dotted lines (for the difficult condition at .854, and for the easy condition at .981).