American Psychological Association
Psychology and Aging

0882-7974/18/$12.00
2018, Vol. 33, No. 8, 1215–1222
http://dx.doi.org/10.1037/pag0000320

BRIEF REPORT

Windows to Functional Decline: Naturalistic Eye Movements in Older and Younger Adults

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Subtle changes in everyday tasks precede and predict future disability in older adults. Eye tracking may provide a sensitive tool for detecting subtle disruption of everyday task performance and informing the mechanism(s) of breakdown. We tracked eye movements of healthy older adults (OA, $n = 24$) and younger adults (YA, $n = 25$) while they passively viewed a naturalistic scene (Passive Viewing condition) and then verbally reported the necessary steps for achieving a task goal (e.g., pack a lunch; Verbalize Goal condition). Participants also completed a performance-based task of packing a lunch using real objects as well as neuropsychological tests. Group (young vs. old) by Condition (Passive Viewing vs. Verbalize Goal) ANOVAs were conducted to analyze eye tracking variables (i.e., fixation rate, number/duration of fixations to target/distractor objects and off objects). Both the younger and older adults made significantly fewer fixations to distractors during Verbalize Goal than Passive Viewing. Also, significant Group × Condition interactions were observed, indicating that younger adults, but not older adults, spent significantly more time viewing targets and less time off-objects in the goal driven, Verbalize Goal condition than the Passive Viewing condition. Goal-directed eye movements correlated with everyday action errors and tests of executive functioning. Taken together, results support theories of age-related decline in top-down cognitive control and indicate the potential utility of this eye tracking paradigm in detecting subtle age-related functional changes.

Keywords: eye tracking, everyday function, activities of daily living, cognitive aging

Supplemental materials: http://dx.doi.org/10.1037/pag0000320.supp

The subtle cognitive decline associated with typical aging and mild cognitive impairment (Petersen, 2011) is accompanied by changes in everyday functioning that are quantifiable by subjective report (Aretouli & Brandt, 2010; Perneczky et al., 2006; Reppermund et al., 2011) and objective performance-based assessments (Giovannetti et al., 2008; Gold, Park, Troyer, & Murphy, 2015; Griffith et al., 2003; McAlister & Schmitter-Edgecombe, 2013; Schmitter-Edgecombe, McAlister, & Weakley, 2012; Schmitter-Edgecombe & Parsey, 2014). Mild functional changes are strong predictors of future cognitive decline and conversion to dementia (Gomar, Bobes-Bascaran, Conejero-Goldberg, Davies, & Goldberg, 2011; Purser, Fillenbaum, Pieper, & Wallace, 2005) but remain poorly understood, partly because there are few available experimental paradigms to investigate subtle changes in everyday functioning. Performance-based paradigms, such as the Naturalistic Action Test (NAT), that measure “microerrors,” defined as the inefficient but not overtly erroneous execution of everyday task steps (e.g., mis-reaching toward nontarget objects), address this gap. Microerrors increase as a function of task complexity (Seligman, Giovannetti, Sestito, & Libon, 2014) and older age (Rycroft, Giovannetti, Divers, & Hulswit, 2018) and are significantly correlated with performance on cognitive tests. However, microerror analyses may miss early stage cognitive errors (e.g., distractor interference) that may not be observable in movements by the hands. Additionally, the video recording and human analysis required to code microerrors is labor-intensive and time-consuming, limiting the potential for widespread implementation. Automated eye tracking methods have great potential to address limitations of performance-based testing, as age-related changes in visual atten-

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Funding was provided by the National Science Foundation Graduate Research Fellowship Program under Grant DGE-114462 (Sarah Seligman Rycroft), National Institute on Deafness and Other Communicative Disorders NIDCD R01 DC013063 (Jamie Reilly), and Thomas E. Shipley, Jr., Research Prize (Sarah Seligman Rycroft). No conflicts of interest exist. A portion of the data in this paper that supported the validity of the eye-tracking paradigm was included in a poster presentation at the 2016 annual International Neuropsychological Society conference. The major findings in this study regarding group differences in eye tracking variables and relations between eye tracking variables and everyday action errors and neuropsychological measures have not been presented elsewhere.

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tion and top-down control of eye movements during everyday tasks have been documented and linked to functional difficulties. Here we investigated age-related variability in eye movements while viewing everyday objects. Findings from studies of target detection and naturalistic action informed our hypotheses.

Studies of Target Detection

Studies of target detection have demonstrated an age-associated reduction in the "zoom lens" (Eriksen & St. James, 1986; Lauwereyns, 1998) or "useful field of view" of visual attention (Rosler, Mapstone, Hays-Wicklund, Gitelman, & Weintraub, 2005), as older adults (OA) typically make more eye movements to survey the same area as younger adults (YA). This has been reported in a variety of target-detection tasks (Mapstone, Rösler, Hays, Gitelman, & Weintraub, 2001) and is exacerbated by increased cognitive load (Sekuler, Bennett, & Mamelak, 2000). A reduction in the zoom lens, indexed by total fixations, also has been associated with poor driving performance in OA (Clay et al., 2005). The "zoom lens hypothesis" predicts OA will make more fixations than YA when viewing an array of everyday objects, particularly under conditions of increased cognitive load.

Studies of Naturalistic Action

Healthy YA show a systematic pattern of eye movements while performing everyday tasks suggesting that eye movements are strongly influenced by the task goal. Distractor/irrelevant objects are rarely fixated, and target/relevant objects are typically fixated before use (i.e., "look-ahead" fixations; Land, Mennie, & Rusted, 1999; Pelz & Canosa, 2001). Top-down control of eye movements during everyday tasks is diminished in neurological patients with severe functional impairment, with evidence for fewer "look-ahead" fixations and increased distractor fixations compared to healthy controls and patients without severe functional impairment (Forde, Rusted, Mennie, Land, & Humphreys, 2010; Morady & Humphreys, 2011). Top-down cognitive control mechanisms degrade over the life span, with age-related difficulties in the ability to represent, maintain, and update task-relevant contexts (Braver et al., 2001) and inhibit irrelevant information (Gazzaley, Cooney, Rissman, & D'Esposito, 2005). To our knowledge, evidence for weakened top-down control of visual attention during everyday task performance has not been investigated in healthy OA. However, according to the top-down control hypothesis, OA should show more fixations to distractors and fewer target and look-ahead fixations in goal-directed tasks than YA.

Current Study

The current study was conducted as part of a larger project focused on subtle differences in everyday function between OA and YA. A prior publication from this project showed that on the NAT, OA made significantly more microerrors than YA when completing the relatively complex lunch task (Rycroft et al., 2018). OA and YA did not differ on the simpler coffee-making task or on variables reflecting more egregious errors (e.g., omissions of task steps) or completion times. Microerrors on the complex task, but not the simple task, were associated with self-reported functional difficulties and neuropsychological measures (Rycroft et al., 2018; Seligman et al., 2014).

The primary aim of the current study was to determine whether this same cohort, known to differ in their ability to smoothly execute a complex everyday task, would also demonstrate age differences in goal-directed eye movements while viewing everyday objects. Eye movements were measured while viewing everyday objects with a task goal (Verbalize Goal condition) and compared to a control condition in which the same objects were viewed passively, without a goal in mind (Passive Viewing condition). To test predictions of the zoom lens hypothesis, analyses examined whether OA made more total fixations than YA, particularly in the Verbalize Goal condition, which imposed a greater cognitive load than the Passive Viewing condition. To evaluate the top-down control hypothesis, analyses evaluated differences in the pattern of eye movements between OA and YA. Specifically, we investigated whether older adults looked less frequently (fixations) and for less time (dwell time) toward target objects and more frequently and for more time to distractor objects and completely off-task locations during goal-driven viewing. We also analyzed whether, as predicted by the top-down hypothesis, OA made fewer "look-ahead" fixations than YA at the beginning of the task, reflecting weaker planning.

The zoom-lens and top-down hypotheses are not competing accounts of visual behaviors. To our knowledge they have not been evaluated in any single study of naturalistic eye movements, but studies of simple target detection have shown that the size of the zoom lens may be influenced by top-down control (Van der Stigchel et al., 2009). Furthermore, the size of the zoom lens may influence the extent to which distractors elicit interference, as objects outside of the attentional window are not processed (Lavie, 2010). Thus, group differences in total fixations were considered before interpreting differences in patterns of fixations to targets and distractors.

As a secondary aim, we explored correlations between goal-directed eye movements and (1) measures of everyday action microerrors to elucidate potential visual mechanisms of subtle functional difficulties and (2) neuropsychological measures to further understand observed group differences in visual behaviors.

Method

Participants

YA and OA were recruited from Temple University's undergraduate community, from the Osher Lifelong Learning Institute, and through advertisements distributed throughout Philadelphia. Participants were required to meet the following criteria: ages 18–22 years or 65–70 years; fluent in English; living independently; no self-reported history of disorders that affect cognition (e.g., schizophrenia, brain injury, etc.); no current symptoms of moderate to severe depression (Geriatric Depression Scale; GDS >20; Yesavage, 1988; Beck Depression Inventory; BDI >19); and no severe sensory/motor impairments. OA were screened for dementia via a brief interview and a passing score on the Telephone Interview for Cognitive Status (Brandt, Spencer, & Folstein, 1988; Manly et al., 2011).

The current study included 24 OA and 25 YA from a larger sample ($N = 52$) described in Rycroft et al. (2018). Three participants from the original cohort were not included due to technical problems with the eye tracker. Demographic characteristics and neuropsychological tests scores for each group are shown in Table

1. The groups did not differ in sex distribution, but OA completed more years of education and included a larger proportion of self-identified Caucasians. The education difference was not considered meaningful, because YA were active undergraduates on track to complete college degrees. Additionally, education and race did not correlate significantly with eye-tracking measures, and as such were not included as covariates in subsequent analyses.

Participants completed a neuropsychological battery that is described in supplementary Table 1. OA obtained higher estimates of intellectual functioning based on reading scores; however, YA performed significantly better than older adults on tests of executive function and episodic memory. The groups did not differ on tests of verbal fluency or naming. When compared to their same-age peers (scaled scores), OA performed in the average to high average range on all measures (data not shown; see Rycroft et al., 2018). OA also completed questionnaires regarding everyday functioning, which showed generally intact functioning, consistent with healthy populations (Functional Activities Questionnaire *M* = 1.29, *SD* = 1.52; Pfeffer, Kurosaki, Harrah, Chance, & Filos, 1982; Instrumental Activities of Daily Living Scale *M* = 8.83, *SD* = 1.55; Lawton & Brody, 1969).

Procedure

Study procedures were approved by the Temple University Institutional Review Board. All participants completed a single study session lasting approximately 2 hr. Procedures were completed in the following order for all participants: (1) eye-tracking task; (2) Naturalistic Action Task (reported in Rycroft et al., 2018); and (3) neuropsychological tests and self-report questionnaires. Participants were compensated financially or with course credit.

Eye tracking task. Eye tracking data were collected using a SensoMotoric Instruments (SMI) RED-m 120 Hz infrared remote eye tracker while participants viewed stimuli on a 17-in. Dell monitor using Experiment Center software. Eye tracking variables were computed offline using BeGaze software (SMI, Inc., Boston, MA).

Participants were seated in a quiet room, positioned approximately 60 cm from an infrared eyebar. A 5-point calibration procedure was completed, and the experimental task was initiated after reaching calibration tolerance <0.75°. Participants viewed two scenes of everyday objects (coffee scene, lunch scene), each in two different conditions. In the Passive Viewing condition, participants were instructed to look at the scene as though they had walked into a room and saw the objects on a table. Gaze patterns were continuously tracked for 60 seconds. The Passive Viewing condition was administered to observe the natural pattern of eye movements to the object array without a goal in mind as a control to the second condition. In the second condition (Verbalize Goal), participants viewed the same scene but were instructed to verbally report the steps they would take to complete a specific task (e.g., make lunch). No time limit was imposed, and participants varied in the duration of their verbal response. All participants completed the Passive Viewing condition first followed by the Verbalize Goal condition.

The coffee and lunch scenes used in the study differed in complexity. The *simple* scene (coffee) included five objects to make coffee and four distractor objects. The *complex* scene (lunch) included eight objects to pack a lunchbox with a peanut butter and jelly sandwich, a drink, and a snack (lunch box, thermos, package of cookies, peanut butter, jelly, etc.) and four distractors (spray bottle, plastic cup, razor, etc.), which were interspersed throughout the array. The order of the simple and complex scene presentation was counterbalanced across participants.

For the current study, we focused our analyses on results from the complex lunch scene, because past studies suggest that floor effects with the simple, coffee task limit statistical analyses with OA (Rycroft et al., 2018; Seligman et al., 2014) and a range of

Table 1
Demographic Characteristics and Neuropsychological Test Scores for Each Study Group

Demographic characteristic/Neuropsychological test	Older adults (n = 24)		Younger adults (n = 25)		p-value for older vs. younger adult comparison
	M/%	*SD*	*M*/%	*SD*	
Age	69.25	4.21	19.52	1.26	—
Sex (% men)	37.50%	—	16.00%	—	.110
Education (years)	17.13	2.68	13.32	.95	<.001
Race (% Caucasian)	83.30%	—	52.00%	—	.020
WRAT reading (Estimated IQ)	121.52	16.7	102.92	8.69	<.001
Trail making - scanning (sec)	20.83	3.61	16.32	2.98	<.001
Trail making - numbers (sec)	34.92	9.55	22.76	7.38	<.001
Trail making - letters (sec)	36.91	13.82	22.60	8.85	<.001
Trail making - switching (sec)	92.83	58.87	59.92	15.66	.016
Spatial span (total correct)	14.13	3.84	18.00	3.62	.001
CVLT trials 1–5 (total correct)	45.00	10.56	53.36	8.02	.004
CVLT long delay free recall (total correct)	9.75	3.63	12.68	2.53	.003
CVLT recognition discriminability	2.80	.86	3.57	.53	.001
Letter fluency (total correct words)	46.42	15.70	41.13	6.84	.130
Category fluency (total correct words)	42.83	10.97	42.54	6.59	.995
Boston naming test (total correct)	14.00	1.53	13.88	1.30	.930
Executive function factor score	.59	.88	−.59	.72	<.001
Episodic memory factor score	−.38	.97	.38	.89	.007
Language factor score	.31	1.10	−.31	.79	.028

clinical populations (Giovannetti et al., 2008; Giovannetti, Libon, Buxbaum, & Schwartz, 2002; Humphreys et al., 2000; Schwartz et al., 1998; Schwartz, Segal, Veramonti, Ferraro, & Buxbaum, 2002). A complete list and description of the eye tracking variables collected for this study are found in supplementary Table 2.

Naturalistic Action Task (NAT). As reported in Rycroft et al. (2018), all participants completed a modified version of the NAT (Schwartz et al., 2002) that included the coffee and lunch tasks. Participants were seated at a table containing all of the exact target and distractor objects that were depicted in the eye tracking task, and performance was video-recorded and scored for errors and time to completion. For the current study, we focused on the lunch task and total microerrors, defined as inefficient but not overtly erroneous execution of task steps, including extra actions, imperfect sequencing, and initiation and termination of an incorrect action before completion of the error (Bettcher, Giovannetti, MacMullen, & Libon, 2008; Giovannetti, Schwartz, & Buxbaum, 2007; Seligman et al., 2014). Interrater reliability estimates have shown strong agreement in the total number of microerrors identified on video recordings by two coders ($r = .98$; Seligman et al., 2014). In Rycroft et al. (2018), we showed that OA made significantly more microerrors than YA on the lunch task. Thus, correlation analyses including NAT-lunch microerrors and eye tracking variables were conducted to elucidate potential visual mechanisms associated with subtle action errors.

Analytic Strategy

All variables were inspected for homogeneity of variance and normality; aberrant variables were transformed or analyzed using nonparametric methods. The following variables were not normally distributed: proportion distractor dwell time (Passive Viewing, Verbalize Goal); proportion initial target fixations (Verbalize Goal); proportion off-object dwell time (Passive Viewing, Verbalize Goal); and NAT-lunch microerrors. The proportion of target fixations and target dwell time during the Passive Viewing condition achieved a normal distribution when an extreme low value was replaced with the second smallest value in the group.

Neuropsychological measures, except for estimated IQ, were reduced to factor scores using principal component analyses with the eigenvalue criterion (>1) to determine the number of factors/components and varimax rotation to simplify the interpretation of factors/components. Factor loadings and measures of internal consistency are reported in supplementary Table 3. Results identified three factors: executive functioning/working memory (lower scores reflect better performance), episodic memory (higher scores reflect better performance), and language (higher scores reflect better performance). Mean factor scores for OA and YA are reported in Table 1 and were included in correlation analyses with eye tracking variables.

The primary study aim was to examine differences between OA and YA in visual fixations when passively viewing everyday objects (Passive Viewing) versus when viewing everyday objects with a task goal in mind (Verbalize Goal). Mixed (Group × Condition) ANOVAs were conducted for all eye tracking variables. Predictions were informed by the zoom lens and top-down hypotheses; therefore, the threshold for significance was set at $p < .05$.

A secondary aim included exploring relations between eye movements during goal-driven viewing (Verbalize Goal condition) and NAT-lunch microerrors as well as neuropsychological factor scores. Pearson correlations were conducted for normal variables, and Spearman correlations were conducted for variables that were not normally distributed. Because correlation analyses were exploratory, Bonferroni correction was applied when interpreting statistical significance.

Results

Group Differences in Eye Tracking

Summary statistics of the raw eye tracking data for both scenes and conditions can be found in supplementary Table 4.

Fixation rate. To evaluate predictions from the zoom lens hypothesis that OA would show a greater increase in total fixations in the Verbalize Goal condition than YA, a mixed (Group × Condition) ANOVA was conducted with total fixations (over total time in seconds; fixation rate) as the dependent variable. Results showed a significant interaction, $F(1, 47) = 7.24$, $p = .01$, $\eta_p^2 = .13$, but no significant effect of Group, $F(1, 47) = .02$, $p = .88$, $\eta_p^2 \leq .001$, or Condition, $F(1, 47) = 2.65$, $p = .11$, $\eta_p^2 = .05$. The pattern of the results was not consistent with the zoom lens hypothesis, and all post hoc analyses were nonsignificant. Fixation rate in the Passive Viewing condition did not differ from the Verbalize Goal condition for either group (YA Passive Viewing $M = 2.72$, $SD = .66$; Verbalize Goal $M = 3.09$, $SD = -.41$; $p = .40$; OA Passive Viewing $M = 2.99$, $SD = .40$; Verbalize Goal $M = 2.87$, $SD = .44$; $p = .15$). Between-groups analyses showed no significant differences between OA and YA in the Passive Viewing ($p = .10$) or the Verbalize Goal ($p = .09$) conditions. On average, OA and YA participants made about three fixations per second in both conditions.

Eye movements to target objects. To evaluate predictions from the top-down hypothesis that YA would show a greater shift in eye movements (fixations, dwell times) toward target objects in the Verbalize Goal condition, mixed (Group × Condition) ANOVAs were conducted with proportion target fixations (out of total fixations) and proportion target dwell times (out of total time in ms) as dependent variables. Results for target fixations showed a significant effect of Condition, $F(1, 47) = 116.22$, $p < .001$, $\eta_p^2 = .71$, but no significant effect of Group, $F(1, 47) = 1.32$, $p = .26.$, $\eta_p^2 = .03$, or interaction, $F(1, 47) = 1.91$, $p = .17$, $\eta_p^2 = .04$. As shown in Figure 1, both groups made a higher proportion of target fixations during the Verbalize Goal condition than the Passive Viewing condition ($p < .001$ for both).

The results for target dwell times were consistent with the top-down hypothesis, with a significant effect of Condition, $F(1, 47) = 35.83$, $p < .001$, $\eta_p^2 = .43$, no effect of Group, $F(1, 47) = 1.95$, $p = .17$, $\eta_p^2 = .04$, but a significant Group × Condition interaction, $F(1, 47) = 10.88$, $p = .002$, $\eta_p^2 = .19$. As shown in Figure 1, YA showed a greater increase in the proportion of time spent dwelling on target objects from Passive Viewing to Verbalize Goal ($p < .001$) than did OA ($p = .07$). OA and YA differed significantly in the Verbalize Goal condition ($p = .007$) but did not differ in the Passive Viewing condition ($p = .45$).

Finally, the analysis of initial target (i.e., "look ahead") fixations for the Verbalize Goal condition showed no significant difference

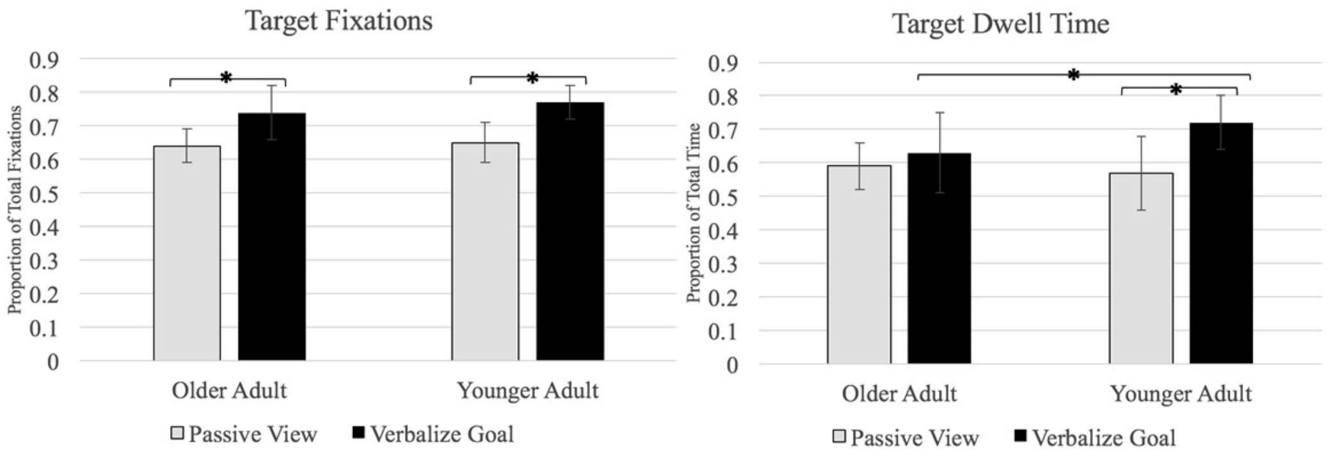

Figure 1. Eye movements to targets. The proportion of Target Fixations and proportion of Target Dwell Time are shown for older and younger adults in the Passive Viewing and Verbalize Goal conditions. The Proportion of Target Fixations was significantly larger for both groups in the Verbalize Goal condition (A). For Proportion Target Dwell time a significant interaction was observed, such that only younger adults showed a significant increase in the proportion of time they spent viewing target objects in the Verbalize Goal condition compared to the Passive Viewing condition, and younger and older adults differed significantly in time spent viewing targets in the Verbalize Goal condition but not in the Passive Viewing Condition (B). Error bars reflect ±1 *SD*. * denotes significant differences at $p < .01$.

between YA ($M = .74$, $SD = .14$) and OA ($M = .74$, $SD = .15$; Mann–Whitney U = 304.50, $p = .93$).

Nontarget eye movements. Eye movements to nontargets also were analyzed to evaluate the prediction from the top-down control hypothesis that YA would show a greater shift in eye movements away from off-task locations (distractors, off-objects) in the Verbalize Goal condition.

Distractor objects (fixations, dwell times). Contrary to prediction, mixed ANOVAs for proportion distractor fixations (out of total fixations) showed a significant effect of Condition, $F(1, 47) = 158.04$, $p < .001$, $\eta_p^2 = .77$, but no effect of Group, $F(1, 47) = .04$, $p = .84$, $\eta_p^2 = .01$, and no interaction, $F(1, 47) = .47$, $p = .50$, $\eta_p^2 = .01$. As shown in Figure 2, both groups made a lower proportion of distractor fixations during the Verbalize Goal condition than the Passive Viewing condition ($p < .001$ for both).

Mixed ANOVAs for proportion distractor dwell times (out of total time in ms) showed a significant effect of Condition, $F(1, 47) = 131.2$, $p < .001$, $\eta_p^2 = .74$, no effect of Group, $F(1, 47) < .001$, $p = .99$, $\eta_p^2 \leq .001$, and surprisingly, no significant interaction, $F(1, 47) = .70$, $p = .41$, $\eta_p^2 = .02$. As shown in Figure 2, both groups spent a lower proportion of dwell time on distractor objects during the Verbalize Goal condition than the Passive Viewing condition ($p < .001$ for both). Thus, despite the finding that OA spent less time looking at target objects in the Verbalize Goal condition compared to YA, OA did not spend more time viewing distractor objects.

Off-objects (dwell time). There was no effect for Group, $F(1, 47) = 1.08$, $p = .30$, $\eta_p^2 = .02$, or Condition, $F(1, 47) = .77$, $p = .39$, $\eta_p^2 = .02$, for proportion off-object dwell time (out of total time in ms), but the interaction was significant, $F(1, 47) = 6.83$, $p = .01$, $\eta_p^2 = .13$. As shown in Figure 2, OA demonstrated a significant increase in proportion of time spent off-object from Passive Viewing to Verbalize Goal ($p = .007$), whereas YA showed no significant difference between conditions ($p = .29$). Also, OA and YA differed significantly in off-object dwell time in the Verbalize Goal condition ($p = .02$) but not in the Passive Viewing condition ($p = .66$).

Correlation Analyses

Everyday action errors. Correlations between goal-directed eye tracking variables and NAT-lunch microerrors were performed to elucidate potential visual mechanisms associated with microerrors and are shown in supplementary Table 5. After Bonferroni correction ($p = .05/7$, .007), only the correlation between microerrors and proportion target dwell time was statistically significant ($\rho = -.46$). Thus, participants who committed more NAT microerrors spent less time viewing target objects during goal-directed visual search.

Neuropsychological tests. Correlations between eye tracking variables and neuropsychological factor scores were conducted to further understand cognitive mechanisms (see supplementary Table 5). After Bonferroni correction ($p < .007$), the Executive Function Factor Score significantly correlated with both target dwell times ($r = -.46$) and off-object dwell times ($\rho = .41$) in the expected direction (i.e., longer dwell times on targets and shorter off-object dwell times were associated with better executive function). The significant correlation coefficients for target and off-object dwell times weakened but remained significant when partial correlations were conducted to control for age (target dwell $r = -.31$, $p = .040$; off-object dwell $r = .37$, $p = .014$).

Discussion

Younger adults and older adults did not differ in total fixations when viewing an array of everyday objects with or without a goal

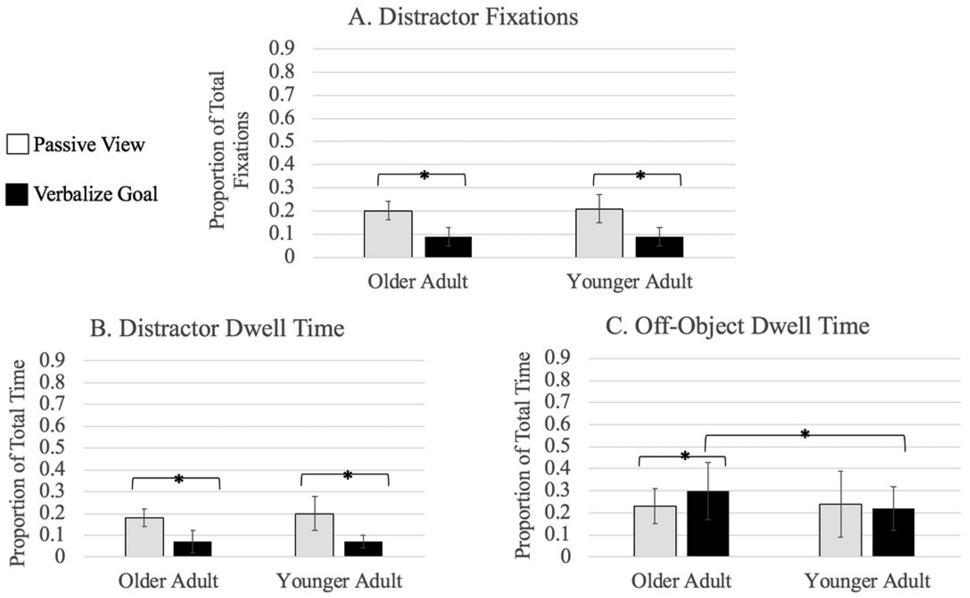

Figure 2. Distractor Fixations and Dwell Time and Off-Object Dwell Time. The proportion of Distractor Fixations (A), proportion of Distractor Dwell Time (B), and proportion of dwell time spent off-objects [Off-Object, (C)] is shown for both groups and conditions. The proportion of Distractor Fixations and Distractor Dwell Time was significantly smaller for both groups in the Verbalize Goal condition. A significant interaction was observed for Off-Object Dwell Time, such that older adults showed a significantly greater increase in the proportion of time they spent off of task objects in the Verbalize Goal Condition, but there was no significant difference for younger adults; and younger and older adults differed significantly in time spent off-objects in the Verbalize Goal condition but not in the Passive Viewing Condition. Error bars reflect ±1 *SD*. * denotes significant differences at $p < .05$.

in mind; however, a significant group difference in eye movement patterns was observed that supported the top-down control hypothesis. Specifically, older adults spent significantly less time viewing target objects and significantly more time viewing off-task objects during goal-directed viewing than younger adults.

Although a reduced zoom lens may affect simple visual search tasks or complex tasks, such as driving, that require distributed visual attention or sustained visual vigilance (Clay et al., 2005; Mapstone et al., 2001), results of total fixations suggested that older adults and younger adults did not differ in their useful field of view when scanning an array of highly familiar, everyday objects, even when required to keep a goal in mind. Counter to the zoom lens hypothesis, the significant Group × Condition interaction for total fixations suggested a tendency for younger adults, but not older adults, to increase their total fixations from the Passive Viewing to the Verbalize Goal condition, which may reflect a normative increase in fixations to cope with the added cognitive load of goal-driven viewing. However, follow-up group and condition contrasts were nonsignificant; therefore, the unexpected significant interaction should be interpreted with caution. Overall, the results suggested no difference in the zoom lens between the groups, which also implies that putative group differences in top-down control did not influence the size of the zoom lens (Van der Stigchel et al., 2009), and that the size of the zoom likely did not contribute to group differences in the capacity to process distractor objects in the array (Lavie, 2010).

Older adults and younger adults showed significant differences in their eye movement patterns from passive to goal-directed viewing of everyday objects that supported the top-down cognitive control hypothesis. As predicted, older adults showed a greater increase in proportion of time viewing target objects with a goal in mind than passive viewing. Contrary to expectation, however, older adults did not spend more fixations/time viewing distractor objects. In fact, objects that were not needed for the task goal (distractors) were hardly ever viewed by either group in the Verbalize Goal condition. Relative to younger adults, older adults spent more time looking elsewhere (at white space and off-screen) during the Verbalize Goal condition. That older adults spent more time off-task only in the Verbalize Goal condition argues against general age-related distractibility or technical difficulties in capturing older adults' eye movements. Although consistent with the top-down hypothesis, further research is needed to determine whether off-screen time reflects distraction by task-irrelevant objects in the environment, aimless eye movements off-screen, or even older adults' tendency to close their eyes in the face of overwhelming cognitive load.

As a secondary aim, associations between goal-driven eye movements and everyday action errors and neuropsychological measures were examined. Significant associations between microerrors and time viewing targets suggest that that microerrors may be explained by older adults' tendency to prematurely move their eyes away from targets during complex tasks that exceed a certain threshold for attentional capacity, potentially leading to temporarily unguided hand movements and unintentional touching of off-task objects. Significant relations between only executive function abilities and target/off-object dwell times, even after accounting for age, offer further support the top-down hypothesis and suggest that executive function abilities may be particularly important for sustaining eye movements to targets during goal-directed activities (Land et al., 1999; Posner & Petersen, 1990).

Several study weaknesses should be mentioned. First, eye movements were not examined during actual performance of everyday tasks, limiting the ecological validity of our results. However, one of our long-term objectives is to develop an automated, efficient, and objective measure of early functional decline, which given current limitations of eye tracking technology is only feasible with a screen-based task. Second, the older adult sample was relatively homogeneous and comprised primarily of college educated, Caucasian individuals, which may limit the generalizability of our findings. Additionally, the Passive Viewing and Verbalize Goal conditions were not counterbalanced. The Passive Viewing condition was performed first for all participants because we were very concerned that participants might find it challenging to avoid thinking of the task goal in the Passive Viewing condition after doing so in the Verbalize Goal condition. However, future replication using a counterbalanced design would elucidate the extent to which our results were influenced by order effects.

The current study also has several notable strengths. To our knowledge, this is the first study of its kind to examine older versus younger adult differences in eye movements during a goal-directed everyday task; prior studies have focused on case studies of neurological patients or on tasks that do not simulate the real-world demands of complex, object-directed everyday activities. The combination of eye tracking methodology, performance-based action assessment, and neuropsychological testing is an additional strength.

In conclusion, our results have theoretical, methodological, and clinical implications. After examining three aspects of eye movements (total fixations, look-ahead fixations, and dwell times), only dwell times on targets and away from objects showed support for the top-down hypothesis. Furthermore, significant relations were observed between target/off-object dwell times and executive function abilities and everyday action errors. Taken together, results suggest that older adults may fail to sustain eye movements on targets due to executive difficulties, which may lead to shallower processing of objects and distractibility, as well as greater task performance inefficiencies. Regarding methodology, the results strongly suggest that future studies should include measures of dwell times along with fixation locations. Finally, the results supported the validity of a novel eye tracking paradigm that may be sensitive to subtle changes in functional ability with age and holds great promise for reducing the labor intensive, time-consuming process often inherent in objective, performance-based assessment of everyday function. Eye tracking measures may improve detection of dementia risk and identify targets for intervention or prevention of functional disability associated with dementia.

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Received November 7, 2017
Revision received October 14, 2018
Accepted October 15, 2018 ■